THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

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THE MOND NICKEL COMPANY LTD • THAMES HOUSE, MILLBANK, LONDON, S.W.1
Telephone:- Victoria 3888

The Engineering,
Marine & Welding
Exhibition
and
The Foundry Trades
Exhibition

The Mond Nickel stand (No. 2, Row G) will be devoted to demonstrations of properties associated with the products of the Company. They will illustrate the properties of S.G. Iron, the physical properties of the nickel-iron alloys and the low-temperature properties of nickel alloy steel. There will also be exhibits featuring rhodium plating and the welding of nickel alloys.

Olympia - London - September 1st - 15th, 1955

ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

GENERAL

Thermal Conductivity of Metals at Low Temperatures

H. M. ROSENBERG: 'The Thermal Conductivity of Metals at Low Temperatures.'
Philosophical Trans., Royal Soc., London, Series A, 1955, vol. 247, Mar. 24, pp. 441–97.

Study of data previously available on thermal conductivity at low temperatures revealed considerable disagreement between theory and experimentally determined values, indicating the need for further information. These considerations gave rise to the systematic research reported in this paper: the primary object was the accumulation of a volume of comparable data on the basis of which a general picture of the heat conductivity of metals at low temperatures could be built up. The determinations were made on 32 metals of high purity (greater than 99·9 per cent.): in most cases the temperature range was 2° to 40°K. (−271° to −233°C.), and in some cases this was extended to 90°K. (−183°C.). The effect of high magnetic fields on thermal conductivity of metals in the normal state was also investigated, and electrical-resistance measurements were taken on some of the specimens, to ascertain the variation of the Wiedemann-Franz relation.

The first sections of the paper deal with the apparatus and the experimental technique used. This is followed by an outline of the present state of the theory, and a report of the experimental measurements. Finally, the results are discussed in relation to theoretical predictions, and a method of estimating thermal conductivity of a metal sample is suggested.

Nickel (99·997 per cent. purity; vacuum-annealed rod) showed the highest thermal conductivity among the metals of Group VIII, 3d transition group.

Thermal Conductivity of Nickel: Apparatus for Measurement

M. MOSS: 'Apparatus for Measuring the Thermal Conductivity of Metals in Vacuum at High Temperatures.' *Rev. Scientific Instruments*, 1955, vol. 26, Mar., pp. 276-80.

The design of measuring apparatus described is a modification of that by VAN DUSEN and SHELTON: see *Nat. Bur. Standards Jnl. of Research*, 1934, vol. 12, pp. 429-40. The method consists essentially of measuring both the axial temperature gradient and the transfer of heat, under steady-state conditions, in a thermally shielded cylindrical rod of the metal under test, which is heated at one end and cooled at the other. Tests were made on nickel, zirconium and a zirconium-tin alloy, from room temperature up to temperatures between 500° and 700°C. The results for electrolytic nickel (99·65 per cent.) are compared with those determined by VAN DUSEN and SHELTON on (*a*) very-high-purity nickel (99·94 per cent.) and (*b*) commercial malleable nickel. In all cases the curves show abrupt breaks in the region of the Curie temperature: the data exhibit 'an orderly correlation between purity and thermal conductivity.'

Testing of Sintered Metal Components

BRIT. STANDARDS INSTN.: 'Acceptance Tests for Sintered Metal Powder Components.'
B.S. 2590: 1955. Price 3/-.

The standard makes recommendations with regard to the sampling and testing of finished sintered components, as distinct from the metallic powders from which they are produced.

Requirements covered include freedom from defects, selection of test samples, chemical and metallurgical tests, and tests for determination of bulk density, apparent porosity, tensile strength, compressive strength, impact-resistance, bend quality, hardness, shear characteristics, and resistance to crushing.

An appendix gives details of test pieces to be used for mechanical testing (since normal B.S. standards are not suitable for the sintered components), and recommends procedure for impregnating porous sintered components with oil (for density and porosity testing), and for removal of impregnant.

Inert-Gas Metal-Arc Cutting of Nickel and Nickel Alloys

See abstract on p. 108.

NICKEL

Purification of Nickel for Radiation Experiments

S. E. SINGER and M. H. KURBATOV: 'Radiochemical Purification of Nickel in Macro Quantities.'
Jnl. Amer. Chemical Soc., 1954, vol. 76, Sept. 20, pp. 4739–40.

Details are given of procedure developed for purification of nickel prior to exposure to radiation. A modified dimethylglyoxime–complex technique was employed: procedure in which solid dimethylglyoxime was used was found to be specially advantageous for work of this type.

Thermal Conductivity of Nickel: Apparatus for Measurement

See abstract on p. 99.

Thermal Conductivity of Metals at Low Temperatures

See abstract on p. 99.

Magnetostriction/Temperature Relationships in Nickel

W. D. CORNER and G. H. HUNT: 'The Temperature Dependence of Magnetostriction in a Nickel Crystal.' *Proc. Physical Soc., Sect. A*, 1955, vol. 68, Mar. 1, pp. 133–44.

Although many investigations on the magnetostriction of polycrystalline specimens have been reported, few measurements have been made on single crystals. Knowledge of the single crystal magnetostriction over the range of temperatures up to the Curie point is, nevertheless, desirable for many purposes, e.g., the calculation of magnetic effects of stresses. The present authors have therefore measured the changes in length which accompany magnetization in the [100] and [111] directions in a single crystal of nickel, over the range $-180°$ to $+360°$C. (Curie temperature 358°C.).

The specimens used were in the form of prolate spheroids, with major axes lying along the [100] and [111] crystallographic directions.

The results obtained indicate that at low temperatures the magnetostriction below saturation varies with magnetization approximately in the manner given by the domain treatment suggested by HEISENBERG (*Zeitsch. Physik*, 1931, vol. 69, p. 287), and that with rising temperature there is a steady departure from the calculated values. Saturation magnetostriction was found to depend on temperature in a way which did not correspond to any known theory.

Nickel in Electronic Engineering

The papers presented at Le Congrès International Cinquantenaire Cathode Oxydes, 1954, included a series dealing with the composition, properties and uses of nickel and high-nickel alloys used for components of electronic valves.

The papers are reprinted in *Le Vide*, as shown below.

A. M. BOUNDS, T. H. BRIGGS and C. D. RICHARD: 'Development of New Cathode Nickels with Improved Performance', *Vide*, 1954, vol. 9, May, pp. 18-21.

This paper describes the properties of three new alloys, designated, respectively:

Cathaloy A-30, which contains 0·07–0·12 per cent. of aluminium as the reducing agent for the oxide coating.

Cathaloy A-31, which is a magnesium-activated alloy, containing 3·75–4·25 per cent. of tungsten.

Cathaloy A-32, which contains 4 per cent. of tungsten and 0·10 per cent. of aluminium.

In all the three alloys the silicon content has been kept to a minimum, and other elements are maintained at limits as low as are practically obtainable by good metallurgical procedure. The nominal contents of the other elements are as follows: copper 0·016, iron 0·040, magnesium 0·029, manganese 0·058, silicon 0·012, titanium 0·002, per cent. Alloys A-30 and A-31 have already been successfully used in many types of tube, and even better results are anticipated with A-32, which, like the earlier alloys, has been thoroughly evaluated by means of the A.S.T.M. standard diode and other tests.

J. CHALLANSONNET: 'Nickel in the Manufacture of Oxide Cathodes', *ibid.*, pp. 22-7.

This paper deals with the current stage of development and practice in France, and other European countries. The composition ranges of the various grades of American, British and Continental nickel, and of high-nickel alloys used in electronic equipment, are tabulated. In discussion of the influence of some other elements on nickel, phase diagrams are presented of the systems nickel-magnesium, nickel-silicon, nickel-oxygen and nickel-sulphur. Details are given of projects now under way in France for standardization of cathode nickel. Later sections of the paper deal with extraction of gases from nickel and the sublimation of volatile elements in vacuo at high temperatures.

J. RICHARDS: 'Experimental Results on the Heating of Cathode Nickel in Vacuum', *ibid.*, pp. 28–32.

The author records measurement of the amounts of gas (oxygen, hydrogen, carbon monoxide and carbon dioxide) evolved under various conditions of pressure, temperature, etc., and a study of the evaporation, in vacuo, of volatile constituents (especially magnesium). Such data are believed to give valuable guidance as to the probable behaviour of nickel in electronic tubes.

N. THIEN-CHI: 'Some Aspects of the Metallurgy of Nickel for Thermionic Cathodes', *ibid.*, pp. 33–41.

The influence of the following elements, on the properties of cathode nickel, is discussed: magnesium, aluminium, silicon, tungsten, titanium, carbon, manganese, chromium, iron, sulphur and copper. The author argues that, in order to obtain the purity and close control of composition essential for nickel used in electronic components, production by the powder-metallurgy method has many advantages. The sequence of operations involved in this process is described, with particular reference to its use on pure nickel, and on nickel containing tungsten or titanium. Alternatively, for high-nickel materials containing elements which introduce difficulties in

the application of powder-metallurgy technique, vacuum melting may advantageously be used.

L. PIATTI: 'Premature Failure of Very Thin Nickel Filaments containing Aluminium and Magnesium, due to Rapid Recrystallization, with Grain-Boundary Slip', *ibid.*, p. 42.

This note is published as a contribution to the study of the influence, on oxide-coated cathodes, of the presence, in the metal of the cathode, of elements favouring the reduction of barium oxide. A photomicrograph shows the fracture of a filament of nickel containing aluminium and magnesium, after about 100 hours of service under normal conditions. No abnormal feature could be found in the nickel wire concerned.

D. A. WRIGHT: 'The Influence of the Physical and Chemical Properties of the Coating on the Emission from the Oxide Cathode', *ibid.*, pp. 58–69.

The emission investigations described were carried out with various designs of simple diode. The cathodes consisted of high-purity electrolytic nickel or of nickel to the 'O' specification currently used in Britain for valve cathodes (for details of composition see publication referred to below). Single, double and triple carbonate coatings were included in the studies.

G. A. GIGER: 'Migration of Impurities at the Nickel Oxide Interface in Oxide Cathodes', *ibid.*, July-Sept., pp. 125–8.

The interface formed on various types of nickel, after 1,000 hours of operation, was chemically analysed, as well as the metal of the cathode. Increased percentages of magnesium, silicon, barium and strontium were found in the interface, but the contents of copper, iron and manganese were the same as those in the basis nickel. The stages at which the changes in the composition of the interface take place were investigated. Interface impedance could be correlated only with silicon content.

Nickel and Nickel Alloys in Electronic Valves

HENRY WIGGIN AND CO. LTD.: 'Nickel and Nickel Alloys in Electronic Valves.' *Publn.* 901,* 1955; 21 pp.

The publication opens with a condensed summary of the overall requirements which must be met by materials to be used in electronic valves, and indicates, by a review of the properties characteristic of nickel and high-nickel alloys, the suitability of these materials for such applications.

A detailed account is then given of the specific types of nickel-containing material which are particularly acceptable for individual components: consideration is given to cathodes, grids, anodes, non-magnetic components, support rods and wire, springs, and glass-to-metal seals. The discussion is illustrated by photographs showing typical applications of nickel and its alloys in the components mentioned.

The tabular reference data included cover compositional limits of A, GFA, O, HPA and HPB nickels; of manganese-containing nickel (as used for grids); of Nilo alloys Nos. 36, 42, 48, 50, 475 and K, and of the following other nickel-containing alloys in general use in this industry: Ferry, Brightray S, Inconel, Ni-Span C and Nimonic 90. Mechanical and physical properties of many of these materials are also given.

* *We shall be pleased to supply a free copy of this publication.*

Nickel Diffusion Leak

E. R. HARRISON and L. C. W. HOBBIS: 'Nickel Diffusion Leak for Hydrogen.' *Rev. Scientific Instruments*, 1955, vol. 26, Mar., pp. 305–6.

The authors discuss the relative merits of palladium and nickel as materials for construction of diffusion leaks in apparatus in which a regulated supply of purified hydrogen is required. They give illustrated details of a nickel leak which has proved satisfactory.

Nickel Catalysts

Y. URUSHIBARA and S. NISHIMURA: 'Procedure for the Preparation of a New Nickel Catalyst.' *Bull. Chemical Soc., Japan*, 1954, vol. 27, p. 480.

Detailed instructions are given for preparation of a nickel-zinc hydrogenation catalyst, by precipitation from aqueous nickel chloride by a boiling suspension of zinc dust in water. The catalyst is claimed to show a high degree of activity.

Nickel-containing Catalysts for Treatment of High-Sulphur Gasoline

R. M. CASAGRANDE, W. K. MEERBOTT, A. F. SARTOR and R. P. TRAINER: 'Selective Hydrotreating over Tungsten-Nickel Sulphide Catalyst. Treatment of Cracked Gasolines.' *Industrial and Engineering Chemistry*, 1955, vol. 47, Apr., pp. 744–52.

The utilization of sour crude oils to meet the demand for petroleum products has considerably accentuated the problems of the refiner. The increased sulphur content of gasoline fractions is found to contribute to fouling of engines, and may be responsible for increased engine wear, especially under low-temperature driving conditions. Sulphur compounds also have an adverse effect on the susceptibility of fuels to improvement by tetraethyl lead, necessitating higher concentration of TEL to obtain a given unit improvement in octane number. The problem of meeting sulphur specifications laid down for various grades of petrol, and control of the deleterious effects of sulphur compounds is therefore becoming an increasingly urgent matter.

This paper makes a contribution to the problem, describing a selective hydrotreating process in which a tungsten-nickel sulphide catalyst is employed to desulphurize and improve the stability of cracked gasoline.

At optimum conditions, 50–60 per cent. sulphur reduction, 90 per cent. conjugated diolefine removal

and 10–20 per cent. mono-olefine saturation are obtained with a processing period of 10–15 barrels of fuel per lb. of catalyst before regeneration is necessary. Isomerization of the olefines over the tungsten-nickel sulphide catalyst produces sufficient upgrading of the olefine fraction to compensate for the octane loss due to saturation. Improved susceptibility to lead tetraethyl treatment is effected by reduction of sulphur, and the removal of conjugated olefines results in marked reduction in the amount of inhibitor required.

See also:

W. K. MEERBOTT and G. P. HINDS: 'Selective Hydrotreating over Tungsten-Nickel Sulphide Catalysts. Reaction Studies with Mixtures of Pure Compounds.' *ibid.*, pp. 749–57.

The work reported in the previous paper was concerned with the practical aspects of selective hydrotreating of cracked gasolines. The second paper deals with the mechanism of some of the reactions observed.

Nickel-containing Catalysts in Production of Motor Fuel

J. P. HOGAN, R. L. BANKS, W. C. LANNING and A. CLARK: 'Polymerization of Light Olefines over Nickel Oxide-Silica-Alumina.' *Industrial and Engineering Chemistry*, 1955, vol. 47, Apr., pp. 752–7.

Refinery cracked gas contains significant quantities of ethylene which are not recoverable by polymerization over catalysts now in commercial use. This paper describes continuous-flow bench-scale experiments on the polymerization of ethylene and propylene, separately and in admixture as cracked gas, and demonstrates that nickel oxide on silica-alumina is highly active for this reaction, even at high ethylene dilution.

Corrosion of Nickel at Elevated Temperatures: Reference Data

See abstract on p. 117.

Oxide Films Formed on Nickel

J. S. HALLIDAY and W. HIRST: 'The Examination of Oxide Films by Reflection Electron Microscopy.' *Proc. Physical Soc., Sect. B*, 1955, vol. 68, Mar. 1, pp. 178–81.

The work reported was the outcome of an investigation of the frictional behaviour of oxide films on metals, made by HIRST and LANCASTER (*Proc. Roy. Soc., A*, 1954, vol. 223, p. 324). This work indicated that for a given metal, e.g., copper, the protection afforded by an oxide film could depend on the rate at which the film grows. Optical examination of the films revealed no differences which could account for their frictional behaviour, and films having widely different frictional characteristics were shown, by electron diffraction, to be crystallographically alike. Reflection electron microscopy, reveals, however, the existence of topographical differences which satisfactorily account for the differences in mechanical properties. The work included study of the effects of oxidation on aluminium, nickel and copper surfaces.

Electrical Conductivity of Nickel Oxide

R. LINDSAY and J. J. BANEWICZ: 'Conductivity of Nickel Oxide as a Function of Temperature and Surrounding Atmosphere.' *Bull. Amer. Physical Soc.*, 1955, vol. 30, Apr. 28, p. 36.

Abstract of paper to April 1955 meeting of the American Physical Society.

The electrical conductivity of NiO was determined at temperatures of 200°–1000°C., in atmospheres containing oxygen at partial pressure of 3–760 mm. of Hg.

Nickel-Carbonyl/Phosphorus Compounds

L. MALATESTA and A. SACCO: 'Substitution Products of Nickel Tetracarbonyl with Compounds of Tricovalent Phosphorus.' *Annali di Chimica*, 1954, vol. 44, pp. 134–8; *Chemical Abstracts*, 1954, vol. 48, p. 13,516.

A report is made on twelve new compounds which were prepared to determine the influence of different linkages in the phosphorus compounds, on their ability to substitute for carbonyl in $Ni(CO)_4$. Details are given of structure, colour, melting point and other physical characteristics.

ELECTRODEPOSITION AND OTHER COATING METHODS

Institute of Metal Finishing Annual Conference

The following papers were presented and discussed at the 1955 Spring Conference of the *Institute of Metal Finishing*, held during May:

C. WILLIAMS and R. A. F. HAMMOND: 'The Effect of Chromium Plating on the Fatigue Strength of Steel.' *Paper No.* 1; 23 pp.

The effect of certain electrodeposited coatings in reducing the fatigue strength of the substrate metal has been known for many years, and it is evident from the literature that the lowering of the fatigue limit following electroplating is closely associated with the tensile internal stress present in the coating. No systematic study has, however, been previously made with regard to the relationship between internal stress and the fatigue limit of chromium-plated steel, and of the effects of post-plating heat-treatment. The object of the experimental work described in this paper was to elucidate these factors.

The effect of chromium plating on the fatigue limit of a 2½ per cent. nickel-chromium-molybdenum steel

to B.S. En 25, in two conditions of heat-treatment, was determined. Three thicknesses of chromium were used (0·001, 0·006 and 0·012 in.): fatigue tests were made on the steel unplated, as plated, and after post-plating treatment at temperatures up to 620°C. (520°C. for the harder steel). A detailed account is given of all stages of the work.

The results of the tests confirmed much information which was already available, but also amplify earlier data. The principal conclusions are summarized as follows:

'(1) For En 25 steels of 65 and 80 tons per sq. in. U.T.S., the actual fatigue limit after chromium plating is independent of the hardness of the steel; the *percentage* loss of fatigue strength is naturally greater with the stronger steel.

'(2) A direct relationship (probably linear) exists between the residual internal stress in the chromium deposit and the percentage loss in fatigue limit.

'(3) Fatigue failure of chromium-plated components is governed jointly by the residual internal stress of the chromium and the intrinsic fatigue strength of the electrodeposit. It is tentatively concluded that the fatigue limit of normal hard chromium deposits is 20–25 tons per sq. in.

'(4) The fatigue limit of heat-treated chromium-plated steel varies with the thickness of the chromium deposit, especially in the range 100°–300°C., the loss in fatigue strength being greater for thicker deposits. The fatigue limit 'as plated' is largely independent of the deposit thickness.

'(5) Heat-treatment in the range 200°–300°C. causes further reduction in the fatigue limit below the 'as-plated' value, but treatment at approximately 440°C. restores the fatigue limit to the 'as-plated' level.

'(6) By treating at still higher temperatures, e.g. 520°C., it is possible with some steels fully to restore the fatigue limit of the plated steel to a value corresponding to, or even exceeding, that of the basis material.

'(7) Variations in the fatigue limit after heat-treatment correspond with changes in the internal stress of the chromium deposit resulting from heating. It is tentatively suggested that at relatively low temperatures the initial tensile stress is increased by permanent contraction of the chromium, producing a further reduction in the fatigue limit. At higher temperatures stress relief leads to a progressive reduction in tensile stress, or, at sufficiently high temperatures, to the development of compressive stress due to differential contraction, with consequent recovery of the fatigue strength.

'(8) In engineering applications of hard chromium plating in which the chromium-plated area is subject to critical alternating stress, it is desirable to heat-treat at not less than 440°C. after chromium plating. If the resulting softening of the chromium deposit (to about 650 D.P.H.) cannot be tolerated, or if, as in the case of very-high-tensile steels, the mechanical properties of the steel would be adversely affected by heat-treatment at this temperature, it would be preferable to omit heat-treatment unless the steel were specially subject to hydrogen embrittlement.'

H. FRY: 'A Study of Cracking in Chromium Deposits.' *Paper No.* 2; 21 pp.

An account is given of an experimental exploration of cracking in chromium deposits applied from solutions of conventional compositions, at various temperatures and current densities. Observations were made of the thickness of deposit at which cracking first occurs, of the relation between cracks and striations parallel to the basis metal apparent in etched cross-sections of deposits, and of stress as a function of deposit thickness. From very small thicknesses up to the point at which cracking occurs, stress remains approximately constant or decreases slightly. At approximately the thickness at which cracking begins, the first of a series of striations is formed, the majority of cracks terminating on or close to striations. At approximately the same thickness the mean stress begins to decrease rapidly. It is tentatively suggested that cracking may be due to a reduction in tensile strength associated with structural abnormalities in the region of the striations.

H. J. PICK: 'A New Method of Analysing the Stresses and Strains in Deposited Coatings.' *Paper No.* 3; 15 pp.

It is suggested that the processes leading to stress formation in deposited coatings should, at least for research purposes, be discussed in terms of the secondary effect of stress. The proposal is made that these strains be expressed in terms of the new parameter of 'linear free strain', which is defined as 'that strain which a deposited coating would undergo in a direction parallel to the base if it were deposited on an infinitely thin base of no mechanical strength.'

Formulae for calculating the linear free strain from the curvature of a plated strip have been evolved and the field of application of such formulae is discussed. One of them has been applied to two examples taken from experiments on the electrodeposition of copper.

S. JEPSON, S. MEECHAM and F. W. SALT: 'The Electrodeposition of Iron-Zinc Alloys.' *Paper No.* 4; 20 pp.

Methods are given for electrodepositing iron-zinc alloys containing 3–90 per cent. of zinc, from sulphate baths, and attention is directed to the useful properties of such deposits. Deposition of iron-zinc alloys from chloride baths is also briefly dealt with. A colorimetric method for estimation of zinc in the presence of iron is described.

T. P. HOAR and I. A. BUCKLOW: 'On the Electrodeposition of Tungsten-Cobalt Alloys from Aqueous Solutions.' *Paper No.* 5; 20 pp.

The authors describe the electrodeposition of sound,

coherent deposits of tungsten-cobalt alloys containing up to 60–66 wt. per cent. of tungsten, from solutions containing sodium tungstate, cobalt sulphate, citric acid and ammonium chloride, adjusted to the required pH with sodium hydroxide.

S. G. BRITTON and R. W. DE VERE STACPOOLE: 'Corrosion Tests of Tin-Cadmium Coatings on Steel.' *Paper No.* 6; 14 pp.

Coatings containing tin and cadmium, produced either as a layered electrodeposit of the two metals or by electrodepositing alloys from sulphate or fluosilicate baths, were subjected to corrosion tests in various types of atmosphere.

A. HICKLING and A. J. ROSTRON: 'The Chemical Polishing of Mild Steel by Hydrogen Peroxide-Oxalic Acid Mixtures.' *Paper No.* 7; 24 pp.

The authors report an experimental study of the reactions of mild steel with hydrogen-peroxide/oxalic-acid mixtures, and define the conditions under which chemical polishing takes place. The observations made are discussed in relation to the general mechanism of the chemical polishing of metals.

S. G. CLARKE and J. F. ANDREW: 'The Electrolytic Oxidation of Copper and Copper Alloys in Hot Alkaline Solution.' *Paper No.* 8; 15 pp.

Electrolytic oxidation of copper, brass, and aluminium bronze in hot 15 per cent. caustic soda solution containing a small addition of molybdic oxide produces a compact, adherent coating which consists essentially of cuprous and cupric oxides. The molybdic oxide plays no fundamental part in the process and is necessary only where the deepest black shade of coating is required. The formation of the coating appears to take place through the initial and continued production of cuprous oxide, part of which is further oxidized to cupric oxide. Such coatings may provide a finish which is stable in conditions not involving severely corrosive attack.

H. WILMAN: 'The Structure and Growth of Electrodeposits, and the Modifications Caused by Brightening Agents.' *Paper No.* 9; 16 pp.

Recent electron-diffraction study of the structure and conditions of growth of condensed deposits and of electrodeposited coatings has led to the conclusion that during electrodeposition, in the conditions usually operative, the immediate surface region of the growing deposit reaches several hundred degrees C., e.g., the orientation and stresses in iron and nickel deposits indicate that the surface temperature exceeds 500°C. The structure and growth of electrodeposits is demonstrated in this paper by reference to electrodeposits of silver made from a cyanide bath on electropolished (110), (100), and (111) faces of a silver single crystal. The influence of bath temperature and composition, and the effect of small amounts of addition agents, on the crystal habit, were also investigated.

A. W. WALLBANK and D. N. LAYTON: 'The Plating of Screw Threads.' *Paper No.* 10; 27 pp.

Problems associated with plating, especially barrel plating, of threaded components are considered, with the particular aim of indicating how specifications should be phrased to ensure good plating, and the thread allowance necessary to accommodate finishes of good quality.

P. M. WALKER, N. E. BENTLEY and L. E. HALL: 'Electroforming in Electronic Engineering.' *Paper No.* 11; 15 pp.

Attention is drawn to the increasing use of electroforming as a method of batch production of electronic radar components. Choice of material for, and methods of preparation of, the mandrels, are major factors. When the mandrel can be mechanically withdrawn, stainless steel can be used: where the shape of the component is such that the mandrel cannot be withdrawn plastic is used and, on completion of electroforming, is removed by means of a suitable solvent. Full details are given of the sequence of chemical operations used for preparation of both types of mandrel. Close attention to the design of the electrodeposition plant is also necessary, and to the method of arranging periodic reverse current: under plating-shop conditions electro-mechanical methods of current reversal are preferred to electronic timers. Procedure for electrodeposition of copper and silver (the metals most generally used for electroformed electronic components) are described in detail in this paper. The importance of stress in the deposits, as affecting the manipulation of the electroformed components, is emphasized and stress measurements on copper and silver electroformed under various conditions are recorded.

N. D. P. SMITH: 'The Electron Microscope in the Study of Paints.' *Paper No.* 12; 10 pp.

A. NICHOLSON and H. A. H. JENKINS: 'The Blistering of Paint Films on Steel Surfaces.' *Paper No.* 13; 16 pp.

THE EARL OF HALSBURY: 'Metal Finishing—Technique or Technology.' *Paper No.* 14; 22 pp.

The main theme of the paper is formal training, at various levels, in technical subjects, a subject which is integrated with the particular needs of the electroplating industry. This discussion is prefaced by some basic comments on education in general. The wide coverage of training required by the electroplater is demonstrated by a list of some of the processes with which he may be concerned, emphasizing the breadth of knowledge called for in present-day conditions, by comparison with the relatively restricted range which sufficed in earlier years. The

ability of technical and technological colleges to provide the training necessary is critically discussed, in relation to recent developments in higher technological education in Britain.

Influence of Physical Condition and the Processing of the Basis Metal in Electroplating

A. E. R. WESTMAN and F. A. MOHRNHEIM: 'The Influence of the Physical Metallurgy and Mechanical Processing of the Basis Metal on Electroplating, Part II. Correlated Abstracts.' *Plating*, 1955, vol. 42, Apr., pp. 417–21.

In continuation of the review referred to in *Nickel Bulletin*, 1955, vol. 28, No. 5, p. 85, a correlation is made of relevant literature covering the following aspects of the subject: general reviews, discussions, and theories; nature of the basis metal; surface of the basis metal (nature of the surface, activation of the surface, cleaning and etching); microgeometry of the basis metal surface; crystal orientation and continuation; the polish of the basis metal (mechanical and electrolytic polishing, polish and pores); stresses in the basis metal; corrosion protection of the base (influence of plate thickness and undercoating, and of roughness of the base, replacement of polishing by other smoothing and levelling procedures). The *bibliography* referring to the reports correlated contains nearly 70 items.

Structure and Properties of Electrodeposited Coatings

'Structure and Properties of Electrodeposits.' *Metal Industry*, 1955, vol. 86, Apr. 1, 8, 15, and 22; pp. 247–50, 273–5, 295–6, 311–13.

A serial account is given of the proceedings at a conference recently organized by the Department of Industrial Metallurgy of the University of Birmingham. The scope of the papers and discussions is briefly indicated below:

R. A. F. HAMMOND: 'The Properties and Engineering Applications of Electrodeposits.'

The author traced the development of the application of nickel and chromium in the engineering field (as distinct from decorative/protective uses), and showed a number of slides indicating components on which such deposits could usefully be employed, e.g., repair of breech blocks, maintenance and repair of hydraulic rams, glass rolls, etc. Reference was made to the importance of securing good adhesion in such deposits, and qualities typical of electrodeposited coatings of nickel and chromium were discussed, e.g., hardness and tensile properties. The influence of coatings on fatigue-resistance of engineering components was also considered, and in this connexion attention was directed to the importance of minimizing the internal stress in the deposited metal.

D. N. LAYTON: 'The Crystal Structure and Properties of Electrodeposited Metals.'

This paper, which could be regarded as in some sense complementary to the preceding one, dealt with the structure of electrodeposits in relation to their physical and mechanical properties and, thus, as affecting behaviour in service. The methods which can be used for examination of crystal structure were reviewed, and consideration was given to the influence, on the structure of electrodeposits, of variables arising in the deposition process, and of the basis metal.

The joint discussion on these two papers included (*a*) reference to methods employed for testing adhesion, thickness, and other properties, and for examination of structure; (*b*) the influence of baths and plating conditions on structure and properties; (*c*) changes occurring in electrodeposited coatings on annealing, and (*d*) other related subjects.

J. W. CUTHBERTSON: 'Electrodeposited Alloys.'

The introductory section of this paper dealt with the more theoretical aspect of alloy deposition, which led to detailed consideration of properties and structure of individual types of alloy coating, e.g., tin–zinc, copper–tin, tin–nickel, tin–cadmium. (The information given on tin–nickel deposits relates to the work done by the Tin Research Institute, of which a description was given in a paper by DAVIES, see *Nickel Bulletin* 1954, vol. 27, No. 5, p. 89.)

Electrodeposition of Nickel with Perfluorinated Acids

J. K. TAYLOR and A. BRENNER: 'Notes on Experiments in Electrodeposition with Perfluorinated Acids.' *Plating*, 1955, vol. 42, Apr., pp. 413–14.

Perfluorinated acids, which have become available during recent years, have a number of interesting properties: they are strong, the salts are very soluble, and solutions of such acids have low surface tension.

The authors report experiments to determine the usefulness of some of these acids in chromium- and in nickel-plating baths.

(1) *Chromium Plating*

In the chromium-plating series trifluoroacetic and perfluorobutyric acids were used separately, in a basis bath containing 400 g./L. of CrO_3.

(2) *Nickel Plating*

The following details are given of the nickel plating experiments:

(a) *Nickel Trifluoroacetate*

A bath consisting of 1*M* solution of nickel trifluoroacetate was prepared in the following manner: Trifluoroacetic acid was neutralized with barium hydroxide and the nickel salt was prepared by adding nickel sulphate to the solution and filtering off the precipitated barium sulphate. The volume was then adjusted to give the required salt concentration. The solution of nickel salt so prepared had a pH of about 3: adjustment to lower values was made by addition of the acid and to higher values by addition of a slurry of freshly precipitated nickel hydroxide.

The nickel was deposited on thin-walled copper tubing. The nickel anodes used were not appreciably attacked in this bath and the pH therefore increased during the run, necessitating adjustment as indicated above. At pH above 4 it proved difficult to produce deposits of nickel, especially at high current densities.

In such cases electrolysis started normally, but after a time a green insoluble basic salt was deposited at the cathode.

All the deposits obtained from this bath showed good ductility.

(b) *Nickel Perfluorobutyrate*

The bath was a 1*M* solution of nickel perfluorobutyrate: methods of preparation were in all respects similar to those used for the trifluoroacetate solution. All the deposits were characterized by poor adhesion and either split or were easily peeled from the cathode. They were rather more brittle than the deposits made from the trifluoroacetate bath.

(3) *Trivalent Chromium*

Efforts to develop trivalent chromium baths with fluorinated acid additions proved unsuccessful.

(4) *Cobalt Trifluoroacetate*

Semi-bright deposits were obtained from a cobalt-plating bath prepared by methods similar to those used for the nickel-plating solution. No quantitative measurements were made of the operation of the bath.

Electroplating on Magnesium

H. K. DELONG: 'Electroplating on Magnesium.' *Metal Progress*, 1955, vol. 67, Apr., pp. 102–8.

This article gives a detailed account of the process used by Dow Chemical Company for electrodeposition on magnesium: the stages include surface conditioning, activation, zinc coating by immersion, copper plating, and final plating with nickel, chromium or other metals. The main features of the recommendations made in the respective sections are summarized below:

Surface conditioning

Methods used for surface conditioning are dictated by the nature of the material (cast or wrought) and by the surface required after plating. Mechanical and/or chemical methods may be employed: solutions recommended are shown below:

For castings: pickling (¼–3 minutes) at room temperature in (a) solution containing (per litre) chromium trioxide 280 g., 70 per cent. nitric acid 25 ml., hydrofluoric acid 8 ml., *or* (b) undiluted solution of 85 per cent. phosphoric acid.

For wrought material: pickling (½–2 minutes), at room temperature, in (a) solution containing (per litre) chromium trioxide 180g., sodium nitrate 30 g., calcium fluoride 2·5 g., *or* (b) solution containing (per litre) glacial acetic acid 28 ml., sodium nitrate 80 g.

Zinc–Immersion Process: the bath most generally used is of the following composition:

	g./L.
Zinc sulphate, monohydrate	30
Tetrasodium pyrophosphate	120
Potassium fluoride	7
or sodium fluoride ..	5
Sodium carbonate	5
Preferred pH range 10·2–10·4	
Operating temperature ..	175°–185°F. (80°–85°C.)

Time of treatment 3–10 minutes, depending on the type of material treated, bath temperature, surface of basis metal, etc. Treatment should be only so long as to ensure complete coverage of the surface with a continuous zinc coating; undue prolongation tends to vitiate adhesion of the plated deposits.

Copper Plating: the following copper cyanide bath has been found satisfactory for the copper strike:

	g./L.
Copper cyanide	41·3
Sodium cyanide	50·8
Sodium carbonate	30·0
Rochelle salt	45·0
Sodium hydroxide	7·5
Free cyanide	5·6
Operating temperature ..	150°–160°F. (65°–70°C.)
pH (colorimetric)	'12·2–12·8.
Cathodic agitation (ft./min.)	8–12

If deeply recessed parts are to be plated, a high current density (30–40 amp. per sq. ft.) is applied for the first 30 seconds to one minute, but after that time it is lowered to 15–25 amp. per sq. ft. Parts not having deep recesses do not require the use of initial high current density. Periodic current reversal (15 sec. forward and 3 sec. reverse) is beneficial. If required, heavier deposits of copper may be made by prolonging the time in the cyanide bath, or by treatment, after striking, in other alkaline copper cyanide or pyrophosphate baths.

Nickel Plating: Given an adequate thickness of copper underlay; nickel can be deposited from any of the conventional baths. For plating tubing and deeply recessed parts the following bath is recommended, since it does not seriously attack magnesium surfaces which are devoid of an initial copper deposit, or on which the copper is abnormally thin:

	g./L.
Nickel sulphate	60
Boric acid	35
Ammonium fluoride ..	65
or	
Ammonium bifluoride ..	50
Wetting agent	0·05
Hydrofluoric acid (when needed to reduce pH of bath to 5·5)	
Operating temperature ..	115°–125°F. (45°–50°C.)
Current density ..	5–15 amp. per sq. ft.

Chromium Plating: is deposited from standard baths; other metals can be electrodeposited over the copper strike.

With regard to the properties of electrodeposited coatings made by the methods recommended, it is stated that adhesion is equivalent to that normally obtained on well plated zinc-base die castings. No quantitative data on adhesion on magnesium-base materials are available, but blistering tests and mechanical adhesion tests indicate satisfactory behaviour. On the basis of extensive tests, it can be stated that electroplating of magnesium provides a practical means of securing a good degree of resistance to corrosion and tarnish and that the protective value of such coatings is comparable with that of plating on other non-ferrous metals such as aluminium and zinc. Graphs demonstrating comparative corrosion-resistance of plating deposited on various bases are included in this article.

Electrodeposited Nickel: Properties and Uses

J. B. MOHLER: 'Diverse Properties Extend Engineering Uses of Nickel Plating.' *Iron Age*, 1955, vol. 175, Mar. 10, pp. 100–3.

The article is a review of the composition of nickel-plating baths in general large-scale use, the properties of the deposits obtained from them, and some of the uses of electrodeposited nickel having various physical and mechanical characteristics. Reference is also made to the electroless plating process and its uses. The information given is culled from four recent authoritative publications.

Specification for Heavy Nickel Plating

MINISTRY OF SUPPLY: 'Process Specification for Nickel Plating (Heavy).' *D.T.D. Specn.* 905A, Feb., 1955.

The specification covers heavy nickel deposits applied
(i) to mild-steel exhaust pipes and other parts, to prevent scaling, and
(ii) to ferrous, copper-rich and aluminium-rich materials, in order to provide a wear-resistant surface, or, where permitted by the Design Authority, for the reclamation of worn or over-machined parts, i.e. 'building-up.'

The schedule lays down general requirements ensuring a satisfactory condition of the basis material, method of preparation of the surfaces for plating (according to D.T.D.901 or 910 specifications, depending on the material to be plated); composition of Watts-type plating solution and conditions of operation; composition of the anode nickel and mode of using the anodes; post-plating heat-treatment for improvement of adhesion, relief of internal stress, etc., and inspection testing. Evaluation of the plated components is by adhesion test (by peeling and/or file, and/or chisel method), and by determination of thickness, local and average.

An Appendix to the specification gives details of treatment suitable for treatment of aluminium-rich material prior to nickel plating. This covers degreasing and pickling procedures, zincate treatment, and copper-plating from a Rochelle type of bath.

Thickness Testing of Electrodeposited Metallic Coatings

A. R. HEATH: 'A Simple Non-Destructive Thickness Gauge for Electrodeposits.'
Metal Finishing Jnl., 1955, vol. 1, Apr., pp. 145–50.

The need for a method of measuring thickness of metallic coatings by rapid and routine non-destructive methods has led to proposals for test techniques employing magnetic, ultrasonic and X-ray methods. Each of the procedures has some advantages, but also inherent limitations, and there is an urgent call for a simple, robust meter capable of measuring thickness of coating irrespective of whether the coating and the basis metal are magnetic or non-magnetic. This paper describes a thermoelectric procedure developed in the laboratories of the British Non-Ferrous Metals Research Association. Descriptive diagrams are included in the report, and the use of the method, on some ten types of plated surface, is described. The applications of the method are exemplified by reference, *inter alia*, to coatings of nickel (dull and bright) on steel, brass, and aluminium.

Polarographic Analysis of Nickel-Plating Solutions

R. DIAZ: 'The Applications of Polarography to the Analysis of Electroplating Solutions.' *Plating*, 1955, vol. 42, Apr., pp. 415–16.

The purpose of the paper is to give an up-to-date list of literature relating to the analysis of electroplating solutions by polarographic methods, and to emphasize the advantages of this technique.

The principles on which polarographic analysis is based are briefly outlined and the main features of the literature relating to analysis of plating baths are summarized. It is pointed out that nickel-plating baths have been the subject of more study in this connexion than any other type of bath. Methods which have been proposed for determination of zinc, lead, cadmium, nickel, copper, sulphates, chlorides and boric acid are reviewed. A *bibliography* of 21 items is attached to the review.

NON-FERROUS ALLOYS

Magnetic Properties of Sigma-Phase Alloys

M. V. NEVITT and P. A. BECK: 'Curie Temperatures of Binary and Ternary Sigma Phases.' *Jnl. of Metals*, 1955, vol. 7, May, Pt. II; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1955, vol. 203, pp. 669–74.

Recent investigations have indicated that the sigma phase is some type of electron compound and it appears likely that investigation of the magnetic properties of sigma-phase alloys will aid in clarifying the nature of the phase.

The work reported in this paper was designed to determine whether or not low-temperature ferromagnetism is characteristic of a large variety of alloys, and to establish the influence, on Curie temperatures, of changes in composition and in lattice parameter. In the first section of the investigation Curie temperatures were measured for a series of σ alloys containing either vanadium or chromium with one or two of the elements manganese, iron, cobalt, or nickel. In the second section data were obtained on the Curie temperatures of ternary iron–cobalt–chromium, iron–chromium–molybdenum and cobalt–chromium–molybdenum alloys, all of σ phase type. It was found that ferromagnetism is a characteristic low-temperature property in a wide variety of σ alloys. Correlation of the Curie temperature of the σ phase with composition may be reasonably well described qualitatively in terms of the contributions of the various component atoms to the saturation moment of the alloy.

Hume-Rothery Phases in Nickel-Copper-Tin Alloys

F. MAZZOLENI: 'The Hume–Rothery Phases in Alloys with more than two Components.'

I. 'The Composition of the Hume–Rothery Phases in Alloys with more than Two Components.'
II. 'Phases with a 7:4 Ratio in the Ni–Cu–Sn System.'
III. 'Phases with Ratios of 3:2 and 21:13 in the Ni–Cu–Sn System.'
Metallurgia Italiana, 1953, vol. 45, pp. 363–5; 366–9; 370–3; *Metallurgical Abstracts*, 1955, vol. 22, Apr., p. 759.

Magneto-Thermal Treatment of Nickel-Cobalt Alloys

H. MASUMOTO *et al*: 'A New Anomaly in the Alloys of Nickel and Cobalt. II. The Cause for the Effect of Magnetic Anneal.'
Sci. Repts., Research Inst., Tôhoku Univ., 1954, vol. 6, pp. 462–8.

The effect of cooling (after annealing) in magnetic fields of various strengths was studied on pure nickel and on nickel–cobalt alloys containing 10, 20, 33·43, 40 and 65 per cent. of cobalt. The observations made are summarized in *Metallurgical Abstracts*, 1955, vol. 22, Apr., pp. 758–9.

Monel Tanks in Fluorine Cells

J. DYKSTRA, S. KATZ, C. B. CLIFFORD, E. W. POWELL and G. H. MONTILLON: 'Improved Medium-Temperature Fluorine Cell.' *Industrial and Engineering Chemistry*, 1955, vol. 47, May, pp. 883–7.

Large quantities of elemental fluorine are now required in various processes being operated under the programme of the U.S. Atomic Energy Commission, and considerable effort has therefore been directed towards lowering fluorine costs and improving the operation of fluorine cells. The progress already achieved in large-scale use of improved designs and techniques indicates that general benefit to the chemical industry may result from this work.

The fluorine cells used are of the medium-temperature type, which have been described previously in this journal. They operate at 100°–105°C., using a fused salt bath of KF.2HF (melting point 71·7°C.). The fluorine is liberated at a carbon anode and hydrogen is liberated at a steel cathode. The characteristics of the improved cell are compared in this paper with those of the Hooker cell, which is the type it most nearly resembles.

Modifications in design and conditions of operation are discussed in detail, and illustrated. They include the following outstanding features:

The cell body consists of a welded Monel tank, with a steel water jacket for cooling and heating. Production experience over a considerable period indicates that change from steel to Monel for the tank has lengthened service life by more than three times. (Nickel-plated steel, although superior to steel for this purpose, was less than half as good as Monel). The separators between the fluorine and hydrogen compartments are also made from Monel, giving four times the life obtained from steel separators.

The anode assemblies are also of modified type, and it is noted that for the anode supports chromium-molybdenum steel has proved most suitable: steel and nickel support bars corroded rapidly, resulting in poor contact and shortened cell life. The same type of steel has been selected (in preference to Monel, copper, or other kinds of steel) for cap screws used for anode support.

Monel is extensively used in the diaphragm assembly: details are given of the screen design. Corrosion of the Monel diaphragms is found to be negligible after continuous service life of more than a year.

Features of operation to which special attention is given include method of preparation of the electrolyte, start-up procedures, normal conditions of working, means adopted for temperature control, and occurrence of polarization.

The major cause of cell failure is broken anodes, considered to be due mainly to explosive re-combination of hydrogen and fluorine or oxygen gases. Occasional failures are experienced from water leaks in the cooling tubes or water jacket of the tank. Cell failures resulting from accumulation of sludge in the electrolyte have been virtually eliminated by the use of Monel and of chromium-molybdenum steel in the cell assemblies.

A 36-cell fluorine plant in which the improved cells are incorporated is described in an associated paper, *ibid.*, pp. 878–83. The installation is working in the Gaseous Diffusion Plants of Carbide and Carbon Chemicals Company at Oak Ridge, Tennessee, and at Paducah, Kentucky, under contract with the Atomic Energy Commission.

Nickel and Nickel Alloys in Electronic Valves

See abstract on p. 101.

Use of Monel for Protection of Steel in Marine Service

See abstract on p. 120.

Inert-Gas Metal-Arc Cutting of Nickel and Nickel Alloys

R. S. BABCOCK: 'Inert-Gas Metal-Arc Cutting.' *Welding Jnl.*, 1955, vol. 34, Apr., pp. 309–15.

The article describes a newly developed process for cutting non-ferrous metals and alloys which normally resist oxidation in the standard oxygen-cutting process. The process is a metal-arc cutting operation, in which a consumable mild-steel electrode is used, with d.c. reverse polarity, and the arc and the active zone are shielded with an inert gas, preferably argon.

Most of the experimental work reported was concerned with aluminium, but reference is also made to the use of the process for cutting copper-base alloys, nickel, Inconel and Monel.

Non-Ferrous Metallurgical Analysis: Review

The April, 1955 issue of *Analytical Chemistry* (Part II) contains a series of reviews of industrial applications of analytical chemistry in various fields. The section on Non-Ferrous Metallurgy, compiled by M. L. MOSS, includes a general survey of new techniques which have recently come into special prominence or have been substantially improved. Later sections cover analysis and determination of individual elements, e.g., aluminium, magnesium, copper, zinc, lead, tin, nickel and cobalt, titanium and zirconium, niobium and tantalum, beryllium, sodium and calcium, uranium, precious metals, etc. The supporting *bibliography* numbers over 200 items. The following summary is made of important developments in analysis of nickel-containing materials:—

'GRAHAM, HITCHEN and MAXWELL determined titanium polarographically in nickel-base alloys and steels, using preliminary electrolysis with a mercury cathode to remove copper and iron (*Canad. Jnl. Chem.*, 1952, vol. 30, p. 661). Good precision was achieved on samples containing 0·2 to 2·4 per cent. of titanium in the presence of iron, nickel, chromium, copper, manganese, and aluminium.

'A gravimetric method for determining niobium in alloys of nickel, cobalt, and chromium was reported by GOLUBTSOVA (*Zhur. Anal. Khim.*, 1951, vol. 6, p. 34). Niobium is hydrolyzed in 2 per cent. hydrochloric acid and can be determined in the presence of 6 per cent. titanium or 1·5 per cent. vanadium. For large amounts of vanadium the niobium pentoxide is fused and re-precipitated. Tungsten in complex alloys of nickel, cobalt, and chromium was determined gravimetrically, using 2,5-diamino-7-ethoxyacridine (*Jnl. Anal. Chem., U.S.S.R.*, 1953, vol. 8, p. 105).

'BUCKLOW and HOAR studied the polarographic determination of tungsten and cobalt using an 'internal standard' method in which a measured amount of the element being determined is added to a solution of the sample for calibration purposes. (*Metallurgia*, 1953, vol. 48, p. 317).'

NICKEL-IRON ALLOYS

Magnetic Investigation of Transformation and Segregation Phenomena in Nickel-Iron Alloys

K. H. VON KLITZING and E. WESSELHÖFT: 'Investigation of Transformation and Segregation Phenomena in Nickel Steels by Means of a Suspension of Magnetite.' *Archiv f.d. Eisenhüttenwesen*, 1955, vol. 26, Mar., pp. 141–4.

The authors describe the application of the Bitter-figure technique to the study of alloys in which two phases of different magnetic susceptibility are simultaneously present, or in which areas of inhomogeneity occur. The specific examples selected were (a) the investigation of the α—γ transformation occurring on prolonged heating of a nickel-iron alloy containing 28 per cent. of nickel, and (b) dissociation phenomena and segregation in a martensitic nickel steel containing 7 per cent. of nickel. Balling up of the magnetite applied in suspension to the surface indicates distribution of residual martensite or patches of segregation. Full details of polishing and techniques of examination are given and the results are illustrated by twelve photomicrographs.

Effect of Low Temperatures on Stability of Nickel-containing Magnet Alloys

A. G. CLEGG: 'Effect of Low Temperature on the Stability of Permanent Magnets.'
Brit. Jnl. Applied Physics, 1955, vol. 6, Apr., pp. 120–3.

Earlier work on the influence of temperature on variation in properties of nickel–aluminium–iron–base magnets has been concerned with the effect of elevated temperatures: the present report deals with changes occurring in a lower range, viz., +60° to —180°C.

The compositions of the alloys from which the magnets were made are shown below:

Material	Average Composition % by weight	Heat-treatment
Alcomax III and Columax	Aluminium .. 7·8 Nickel .. .. 13·5 Cobalt.. .. 25 Copper .. 3 Niobium .. 0·8 Iron balance	Cooled from 1250°C., at 1·2°C. per sec. in a magnetic field; tempered for 48 hours at 590°C., followed by 48 hours at 560°C.
Alnico	Aluminium .. 9·5 Nickel .. .. 17 Cobalt.. .. 12·5 Copper .. 6 Iron balance	Air-cooled from 1250°C., tempered for 2 hours at 600°C.
35% Cobalt Steel.. ..	Carbon .. 0·9 Chromium .. 5·5 Tungsten .. 4·5 Cobalt.. .. 35 Iron balance	Oil-quenched from 950°C.
15% Cobalt Steel.. ..	Carbon .. 1·1 Chromium .. 9·0 Molybdenum 1·5 Cobalt.. .. 15 Iron balance	Air-cooled from 1000°C.

Particular attention was devoted to the effect of composition of the alloys, their demagnetization curves and the working point of the test sample. The results have an important bearing on the stability of magnets used for instruments in high-flying aircraft or in polar regions.

Magnetometer measurements were made of change in magnetization with temperature (—60° to +60°C.)* of magnets of various dimensional ratios made from the above alloys. It was found that with decreasing temperature magnetization increases reversibly, except for the shorter-dimension-ratio magnets in Alcomax III and Columax, for which losses occurred. The influence of tempering, on these losses, is discussed. In the materials of lower coercivity losses occur only with rise of temperature. Whether due to rise or fall of temperature, the losses can be minimized by partial demagnetization by means of an alternating field. The results obtained are correlated with changes in the demagnetization/temperature curves of the respective materials.

Nickel and Nickel Alloys in Electronic Valves

See abstract on p. 101.

CAST IRON

Corrosion- and Heat-Resisting S.G. Iron

SOC. AUTOMOTIVE ENGINEERS: 'Alloy Iron Castings, Ductile, Sand, Corrosion- and Heat-Resistant.' *A.M.S. Specification* 5394, issued Mar. 1, 1955.

The material, treated with magnesium as necessary to meet the tensile and microstructural requirements laid down, is required to be within the following limits: 'Total carbon 2·4–3·0, silicon 2·0–3·2, manganese 0·8–1·6, phosphorus 0·25 max., chromium 1·7–2·4, nickel 18·0–22·0, copper 0·50 max., lead 0·003 max., per cent. Tensile and hardness requirements are prescribed, as determined on test pieces (of specified form) and on the castings, and it is required that the microstructure shall consist of spheroidal graphite with small amounts of carbide in a matrix of austenite, essentially free from flake graphite. It is also laid down that the parts must be capable of being cooled to −75°F. (−59°C.) without the austenite transforming to martensite; parts so cooled, after returning to room temperature, must be sufficiently non-magnetic to prevent a small steel magnet from adhering to the casting.

*In some cases the low-temperature range was extended to −180°C.

Corrosion at Elevated Temperatures: Reference Data

See abstract on p. 117.

CONSTRUCTIONAL STEELS

Transformational Characteristics and Impact Properties of Case-Hardening Steels

H. KRAINER, M. KRONEIS and R. GATTRINGER: 'Transformation Characteristics and Impact Toughness of Case-Hardening Steels.' *Archiv f.d. Eisenhüttenwesen*, 1955, vol. 26, Mar., pp. 131–9; disc. pp. 139–40.

The case and core of case-hardened steels may be regarded as a series of steels of gradually varying carbon content, and in order to arrive at the optimum conditions for heat-treatment it is essential to know the transformation characteristics of steels of compositions corresponding to those of the case at various depths, as well as of the core. The work described in this paper is a contribution to this end. Isothermal T.T.T. curves were set up for typical steels case-hardened to obtain varying and closely controlled carbon contents in the surface layer.

The steels used for the experiments were typical carburizing grades, of the compositions shown below.

Minimum rate of transformation was found to occur with carbon contents of the order of 0·4–0·6 per cent.

A further series of experiments was carried out on nineteen unalloyed and alloy steels, to determine the conditions necessary to secure, by isothermal treatment, complete transformation in surface, transition, and core regions. The steels used included plain carbon, chromium, manganese-chromium, chromium-molybdenum, nickel, nickel-chromium and nickel-molybdenum case-hardening grades.

The final section of the investigation was concerned with the toughness of case-hardened steels, as assessed by impact test. The results demonstrate the outstanding qualities of the chromium–nickel and the 5 per cent. nickel types. Chromium–molybdenum steels show a higher degree of toughness than the chromium–manganese types.

C %	Si %	Mn %	Cr %	Mo %	Ni %
0·23	0·37	1·13	1·17	—	—
0·14	0·28	0·36	0·68	—	3·18
0·21	0·33	0·50	1·99	0·07	2·08

Hairline Cracking in Steel: Zirconium as Preventive

D. R. WOOD: 'A Note on Hairline Cracking in H.F. Melted Low-Alloy Steel Ingots Weighing about 1 cwt.' *Jnl. Iron and Steel Inst.*, 1955, vol. 179, Apr., pp. 317–19.

Earlier laboratory experiments, on a high-nickel-chromium-iron alloy, had shown that porosity believed to be due to hydrogen could be eliminated

by addition of zirconium to the melt. In view of the generally accepted opinion that hydrogen is a contributory factor in causing hairline cracking in steel, tests were carried out to determine the influence of zirconium additions on 'crack-sensitized' heats of a steel of the following composition: carbon 0·3, silicon 0·6–1·0, manganese 0·7, nickel 2·5, chromium 0·65, molybdenum 0·55 per cent. Three series of this steel were examined for susceptibility to hairline cracking:—

(*a*) zirconium-free heats,

(*b*) heats containing additions of zirconium and aluminium,

(*c*) heats treated with zirconium only.

The results (reported in detail) show that on a laboratory scale additions of zirconium inhibit hairline cracking to an extent which depends on the amount of zirconium present: the additions made varied from 0·1 to 0·5 per cent. It is considered likely that in commercial steelmaking the amount of zirconium which would be required to secure immunity from hairline cracking would be appreciably lower than the maximum amount added in these experiments, which were made on steels of which the hydrogen contents had been increased by special means to intensify susceptibility to cracking.

While it is appreciated that zirconium may also produce other effects in steel, e.g., modification of the type and distribution of inclusions, the author urges the practical interest of the observations made, in relation to suppression of hairline cracking in large-scale manufacture.

Nickel Additions to Chromium-Molybdenum-base Steels

See abstract on p. 116.

Fatigue Tests on Rolled Nickel-Alloy Steels

P. H. FRITH: 'Fatigue Tests on Rolled Alloy Steels made in Electric and Open-Hearth Furnaces.' *Jnl. Iron and Steel Inst.*, 1955, vol. 180, May, pp. 26–33. (The paper is a summary of *Iron and Steel Institute Special Report* No. 50, 1954).

The work reported was done in two sections.

The first series of tests was made on steels heat-treated to 60, 80, or 110 tons per sq. in. tensile strength: the work was initiated by the Inclusions Sub-Committee of the Iron and Steel Institute. The steels, which were all manufactured by an approved method, were of the following types:

Carbon 0·25–0·35, nickel 2·75–3·25, chromium 0·50–1·00, per cent., with optional vanadium, molybdenum and tungsten (to specification B.S. S.11).

Carbon 0·27–0·35, nickel 2·30–2·80, chromium 0·50–0·80, molybdenum 0·40–0·70, per cent. (to specification B.S. En 25).

Carbon 0·36–0·44, nickel 2·30–2·80, chromium 0·50–0·80, molybdenum 0·40–0·70, per cent. (to specification B.S. En 26).

Carbon 0·26–0·34, nickel 3·9–4·3, chromium 1·1–1·4, molybdenum 0·2–0·4, per cent. (to specification B.S. S.28).

The conclusions drawn from this series of tests are summarized as follows:—

'Similar longitudinal and transverse reversed-bending fatigue properties were obtained for basic electric-arc (normal-procedure) and acid open-hearth steels heat-treated to 60 tons per sq. in. tensile strength. Increasing the tensile strength to 80 tons per sq. in. did not affect the longitudinal fatigue ratio of neutral or basic open-hearth steels, but in the transverse direction the ratio was reduced. A further reduction in the transverse fatigue ratio was obtained by increasing the tensile strength to 110 tons per sq. in. for basic electric-arc (normal-procedure) and acid and basic open-hearth steels, and a reduction in the longitudinal reversed bending ratio was also obtained.

'Inclusions of the size and type present in the steels examined did not appear to be detrimental to the reversed-bending fatigue properties of the steels heat-treated to 60 tons per sq. in. tensile strength. However, it is considered that extraneous inclusions in massive form will be detrimental. At 80 tons per sq. in. tensile strength the inclusions present in the steels examined began to be detrimental to the transverse reversed-bending fatigue properties, and at 110 tons per sq. in. tensile strength they were detrimental to both the longitudinal and transverse properties.

'Undeformed spherical silicates appeared to be the most detrimental inclusions from a fatigue viewpoint, producing at least 17 per cent. reduction in the longitudinal fatigue limit of basic electric-arc (normal-procedure) steel heat-treated to 110 tons per sq. in. tensile strength.'

The second series of tests, initiated by the Bristol Aeroplane Company, Ltd., was made on carbon-chromium steels to B.S. En 31, heat-treated to a hardness of about 750 D.P.N.

'In the longitudinal direction the best fatigue properties were fairly consistently obtained from neutral or acid open-hearth steel, or from steel manufactured in a basic-lined electric-arc furnace using a siliceous slag. Similar fatigue properties were also obtained on one cast of acid electric-arc steel. The fatigue limit of British basic electric-arc (normal-procedure) steel was 26 per cent. lower than for British neutral open-hearth steel, whilst two Swedish acid open-hearth steels had slightly inferior fatigue properties to the British neutral steel. These low fatigue properties obtained on British basic electric-arc (normal procedure) steel appeared to be due to undeformed spherical silicate inclusions.'

In addition to these main groups of tests, supplementary examination was carried out to determine (*a*) repeated-impact transverse properties of selected British and Swedish steels, (*b*) the effect of overstressing, understressing, and shot-peening, on fatigue properties, and (*c*) the fatigue properties of specimens taken from different positions in an ingot, and from different ingots of the same cast. In this series, steels of

the S.11, S.28 and En 26 nickel-alloy types and the En 31 carbon-chromium steel were used all in the 110-ton tensile condition. Fatigue test results are correlated with structural observations made by microradiographic examination.

Corrosion at Elevated Temperatures: Reference Data

See abstract on p. 117.

Alloy Steels in Fluorine Cells

See abstract on p. 108.

Welding of High-Yield-Strength Steels

A. P. BUNK: 'Welding Procedure Qualification Tests for Six High-Yield-Strength Steels.' *Welding Jnl.*, 1955, vol. 34, Apr., pp. 197S–206S.

The Materials Division of the Pressure Vessel Research Committee of the Welding Research Council has under investigation the suitability, for pressure-vessel service, of six steels of high-yield-strength type. In view of the importance of welding in this connexion, a study of the influence of welding operations on these steels is included in the programme of study. The present report describes welding qualification tests carried out to establish welding procedures by which the requirements of the A.S.M.E. Code for Unfired Pressure Vessels could be met with the high-tensile steels.

The tests were made on three pairs of steels, one pair characteristic of the grades showing 50,000 p.s.i. (22 tons per sq. in.) minimum yield, the second pair representative of the 70,000 p.s.i. (31 tons per sq. in.) group, and the third falling into the 90,000 p.s.i. (40 tons per sq. in.) class. For types used see below:

50,000 p.s.i. (22 tons per sq. in.) min.
(Mn–Mo and Mn–V–Ti steels, both normalized).

70,000 p.s.i. (31 tons per sq. in.) min.
(Ni–Cu–Mo–V steel, normalized and tempered;
Ni–Cu–Mo steel, hot-rolled and stress-relieved).

90,000 p.s.i. (40 tons per sq. in.) min.
(Mn–Cr–Ni–Mo–Cu–V steel, quenched and tempered;
Mn–Mo steel, quenched and tempered).

The main conclusions are summarized as follows:–

'A.S.M.E. Code requirements for manual welding procedure qualification can be met when E7016* electrodes are employed to weld a Mn–Mo steel without preheat, provided a postwelding heat-treatment at 1150°F. (620°C.) is applied. Code requirements are also satisfied when either E8016 (1 per cent. Ni) or E9015 (Mn–Mo) electrodes are utilized under similar conditions of no preheat and 1150°F. postheat. Automatic two-pass submerged melt welds appear to be satisfactory for joining this Mn–Mo steel in the 1-in. thickness.

'Manual welds, made with E7016 electrodes in normalized Mn–V–Ti steel without preheat, fulfil Code requirements, regardless of whether or not a postwelding treatment at 1150°F. is employed. Automatic two-pass submerged-melt welds are suitable for welding this steel in the 1-in. thickness.

'Manual welds, using E10016 (Ni–Mo–V) electrodes on Ni–Cu–Mo–V normalized and tempered steel of 70,000 p.s.i. minimum yield strength, meet Code requirements for procedure qualification when neither preheat nor postheat is employed. Automatic two-pass submerged-melt welds also meet procedure requirements without use of preheat or postheat.

'Manual welds, using E9015 (Mn–Mo) electrodes on hot-rolled and stress-relieved Ni–Cu–Mo steel, meet A.S.M.E. Code requirements without use of preheat, provided a postheat treatment of 1100°F. (593°C.) for 1 hour is employed.

'Quenched and tempered Mn–Cr–Ni–Mo–Cu–V steel of 90,000 p.s.i. minimum yield strength, welded with E12015 (Ni–Mo–V) electrodes, using neither preheat nor postheat, did not consistently meet present Code requirements with respect to the side-bend test for overhead-position welds. Side-bend specimens tested in a jig modified to accommodate a plunger of 1.25-in. radius, instead of the usual 0·75-in. radius, consistently passed the test. In connexion with the side-bend test and its use as a criterion of ductility, a review of the history of the test is recommended, with the view of determining the circumstances surrounding adoption of present jig dimensions. Automatic two-pass submerged-melt welding of this Mn–Cr–Ni–Mo–Cu steel requires further study designed to obtain higher weld-metal strength.

'Quenched and tempered Mn–Mo (0·3 per cent. C.) steel did not consistently meet present Code requirements of side-bend test for the vertical position, when manually welded with E12015 electrodes, employing a 200°F. (93°C.) preheat and no postheat. Using a jig modified to accommodate a 1·25-in. radius plunger, all specimens passed. Comments made above regarding the side-bend test apply also to this Mn–Mo (0·3 per cent. C.) steel. Automatic submerged-melt welds made in the 1·5 per cent. Mn–Mo steel containing 0·3 per cent. carbon did not meet present A.S.M.E. Code requirements. Further study of the submerged-melt process for welding this steel appears to be warranted.'

* For particulars of all numbered electrodes referred to in this summary see American Welding Society Specification A5.5—18T., which is similar to A.S.T.M. Specification A 316—48T. and A.S.M.E. Boiler Construction Code Specification SA—316.

Determination of Molybdenum in Iron and Steel

BRIT. STANDARDS INSTN.: 'Methods for the Analysis of Iron and Steel. Part 34: Molybdenum in Iron and Steel (Absorptiometric Method.)'

B.S. 1121: Part 34: 1955. Price 2/–.

A sulphuric-acid solution of the sample is prepared: tungsten, if present, is held in solution with citrate. Molybdenum and ferric thiocyanates are formed by the addition of ammonium thiocyanate. The thiocyanates are subsequently reduced with stannous chloride solution, titanium being added to catalyse the reaction.

The procedure is suitable for analysis of irons and steels containing up to 5 per cent. of molybdenum. Full

details of the equipment required and of analytical technique are included in the schedule.

Determination of Aluminium in Iron and Steel

BRIT. STANDARDS INSTN.: 'Methods for the Analysis of Iron and Steel. Part 35: Aluminium in Iron, Steel and Ferro-Alloys (after Mercury Cathode Separation).' *B.S.* 1121: Part 35: 1955. Price 2/–.

Aluminium, associated with other residual impurities, is precipitated from the solution (after mercury cathode electrolysis) by adding ammonium hydroxide. The hydroxides are filtered and re-dissolved, and iron, titanium, etc., are removed from the solution with cupferron. Potassium cyanide and ammonium sulphide are added to precipitate, or to fix as soluble complexes, the remaining impurities, and the aluminium is finally precipitated as the quinolate complex and is evaluated bromometrically.

By selecting a weight of sample containing between 0·5 and 10 mg. of aluminium, the method can be employed for estimating aluminium in all the ranges likely to be found in iron and steel. It is applicable to all ferrous materials soluble in dilute sulphuric acid.

Mercury Cathode Electrolysis in Analysis of Iron and Steel

BRIT. STANDARDS INSTN.: 'Mercury Cathode Electrolysis for Use in the Analysis of Iron, Steel and Ferro-Alloys.' *B.S.* 1121C: 1955. Price 2/6.

This recommended method has been prepared primarily for use in conjunction with certain British Standard methods for analysis of ferrous materials, e.g., *B.S.* 1121: Part 35 (see preceding abstract), in which some elements must be removed before the main determination is made.

A sulphuric-acid solution of the sample is electrolysed, using a platinum anode and a mercury cathode, at a high current density. The electrolyte can subsequently be employed for the determination of such elements as aluminium, titanium, vanadium and zirconium.

The procedure described has been satisfactorily employed for the removal of iron, chromium, nickel, cobalt, copper and manganese from alloy steels. Large amounts of molybdenum tend, however, to retard electrolysis.

HEAT- AND CORROSION-RESISTING MATERIALS

Uranium Additions to Cobalt-Nickel-Chromium-base Alloys

G. T. HARRIS and H. C. CHILD: 'Uranium in Heat-Resisting Alloys.' *Jnl. Iron and Steel Inst.*, 1955, vol. 179, Apr., pp. 347–9.

The position of uranium in the Periodic Table indicates its possible usefulness as a strengthening element in heat-resisting alloys. A limited amount of work on cobalt-base alloys, containing also substantial proportions of nickel and chromium, confirms this presumption.

The effectiveness of uranium is comparable to that of niobium, but approximately twice the weight percentage of uranium is required to produce an equivalent effect: this difference is believed to be due to the disparity between the atomic weights of the two elements. Uranium has a more deleterious effect on forgeability than niobium, and it was not found possible to forge alloys containing 4 and 6 per cent. of uranium.

An alloy of cobalt-nickel-chromium-base type containing 2 per cent. of uranium had creep properties somewhat superior to those of the same basis type of alloy containing 1·2 per cent. niobium, particularly in long-time tests. The scaling indices of the two alloys, both in the absence and the presence of vanadium pentoxide, were of approximately the same order.

Cermets containing Nickel and Nickel-Alloy Binders

F. W. GLASER: 'Progress Report on Cermets.' *Metal Progress*, 1955, vol. 67, Apr., pp. 77–82, 138.

This is a critical evaluation of the properties of, and prospects for, various types of cermet which have been tested with a view to determining their suitability for use in high-temperature engineering. The problems associated with testing such materials are discussed: attention is particularly directed to the difficulty of assessing impact-resistance, and some methods proposed for determining this quality are mentioned.

The position now obtaining with regard to practical development of cermets is summarized as follows:

Molybdenum disilicide materials, which at first appeared promising, show such poor thermal-shock resistance as to rule them out for practical utilization.

Chromium-alumina materials show inadequate resistance to impact. Cermets of the *aluminide*, *titanium carbide*, and *boride* types are satisfactory from the point of view of oxidation-resistance, strength, and resistance to thermal shock, and must therefore be evaluated mainly on the basis of impact-resistance.

Titanium carbides are now being produced by a number of firms, in both U.S.A. and other countries. The binder materials vary somewhat according to the proposed end-use of the material: nickel-chromium, cobalt - chromium, nickel - chromium - cobalt, nickel-aluminium and nickel-molybdenum alloy binders are variously employed, and the ratio of carbide to metal is adjusted according to the application for which the cermet is to be used. Oxidation-resistance is much increased with rising amounts of nickel-chromium-cobalt binder: stress-to-rupture values fall with increasing metal content, but a binder content of over 50 per cent. has a markedly beneficial influence on impact strength. By means of infiltration treatment it has been possible to produce surfaces rich in metal, and such impregnated composites show tendency to plastic deformation at the surface rather than to crack propagation during impact testing.

Metal borides have received less attention than the titanium-carbide base type of cermet. The requirement for good resistance to oxidation eliminates all but certain borides of zirconium, titanium and chromium, and of these only the chromium-base borides appear practically promising. In oxidation-resistance and thermal-shock resistance these materials are equal to the titanium-carbide type of cermet, but their impact strength is not up to specification requirements.

In the *aluminide* group, most of the research to date has been on the zirconium, titanium and nickel aluminides. This group shows better ductility and impact-resistance than the titanium-carbide or the boride types, but their high-temperature strength is lower, although sufficiently high to make them satisfactory for applications such as nozzle deflection vanes. It is, however, anticipated that within a relatively short period the aluminides will take a more prominent place in the cermet group.

A review of the current position of development of cermets is also to be found in 'Progress in the Development of Cermets', by F. W. GLASER, published in *Planseeberichte für Pulvermetallurgie*, 1954, vol. 2, pp. 59–70.

Hot-Ductility Testing of High-Temperature Alloys

E. F. NIPPES *et al*: 'An Investigation of the Hot Ductility of High-Temperature Alloys.' *Welding Jnl.*, 1955, vol. 34, Apr., pp. 183S–96S.

This report covers an extensive research carried out at Rensselaer Polytechnic Institute, under the aegis of the Welding Research Council, with a view to elimination of cracking of welded components in straight and molybdenum-containing chromium-nickel austenitic steels stabilized with niobium.

Equipment which had been developed to simulate the time-temperature cycle to which various points in the base metal are subjected during the welding cycle was modified to permit breaking specimens, for test, at selected stages during the cycle, thus permitting study of the hot ductility at various temperatures.

Since the research was of particular significance in relation to the hot ductility of stainless steels used in the construction of large steam turbines, the materials chosen for examination by the technique described were typical of those used in such applications: their composition is shown below.

Reduction in area at fracture in the tensile test was the criterion of ductility.

When heated to temperatures above 2350°F. (1287°C.), and tested at those temperatures, both grades of steel showed an intergranular-type fracture and almost nil ductility. At test temperatures of 1400°–2300°F. (760°–1260°C.) the hot ductility of the wrought 347 steel, measured during the heating portion of the thermal cycles studied, was far superior to that of the Type 316 casting alloy.

The investigation demonstrated clearly that in both materials prior thermal history markedly affects hot ductility. In general, short exposures to temperatures in the region of 2400°F. (1315°C.) caused significant lowering of the hot ductility as measured at temperatures between 1400° and 2300°F. (760° and 1260°C.).

The test used gives promise of revealing significant differences in the elevated-temperature properties of the base metals, which may explain observed differences in weldability.

Nickel-containing Materials in Industrial Gas Turbine

'The Rover Type 1S/60 Industrial Gas Turbine.' *Machinery* (*Lond.*), 1955, vol. 86, Apr. 8, pp. 736–46.

The Rover 1S/60 gas turbine, which is stated to be the smallest produced in the United Kingdom, has been designed to provide a light, compact power plant suitable for various industrial and specialized applications. Power generation and use in pumps are two spheres of operation for which it is particularly well adapted. This article gives a detailed and well illustrated description of the main features of the engine, of pilot-plant experience, and of some of the operations involved in production. Reference is made to extensive use of the Nimonic series of alloys and of austenitic stainless steels for various components.

Stainless Steel Components made from Powder

A. ADLER: 'Stainless Steel Powder Parts.' *Materials and Methods*, 1955, vol. 41, Mar., pp. 118–20.

This article reviews the properties and some of the uses of stainless steel powders made by chemical disintegration of the massive steel. Properties typical of compact material produced from the powders, under varying conditions of pressure and temperature, are tabulated, and representative items for which such materials are suitable are described and illustrated. The items to which reference is made include the following:

Filters, produced from material which is sintered without pressing, producing a porous medium from which units the required shape can be made. Degree of porosity can be varied by size of powder and by control of production conditions, thus providing parts suitable for use in many applications, ranging from aircraft de-icing equipment to filters employed in food-handling.

Structural parts, in which a high degree of density and strength can be secured by production under pressure and temperature conditions regulated according to the

Type of Material	C %	Ni %	Cr %	Mo %	Nb %	Mn %	Si %	P %	S %
Type 316 Casting Alloy modified by niobium	0·07	14·21	17·65	2·20	0·49	0·99	0·95	0·020	0·018
Wrought Type 347 Steel	0·09–0·12	11·53	17·85	—	0·97	1·12	0·49	0·020	0·011

properties called for in service. The influence of the respective operations, on the properties of the final product, are discussed. In structural parts requiring particularly high density, copper and silver infiltration is usefully employed. During sintering the added metal flows into the compact, filling voids, and for certain applications the modification in physical properties resulting from such addition is also utilized, e.g., improvement of electrical conductivity by the presence of silver. Among the uses of powder-produced stainless steel in the structural field, reference is made to driving arms in water meters, tubing and bushings in industrial meters of various types, and small gears, levers and other items in which advantage is taken of corrosion-resisting qualities in combination with strength properties, galling- and wear-resistance and other characteristics.

Useful development has recently taken place as a result of combining metallic and non-metallic powders: Teflon/stainless steel compacts are being employed, for example, in floats working in contact with corrosive solutions. Reference is also made to the use of pre-alloyed stainless steel powders (in flake form) in protective paints, and in spray-welded coatings.

Cost of parts made from powder is still relatively high, due to low rates of production and consumption, but it may reasonably be expected that this situation will progressively improve. As in the case of all types of powder-metallurgy production, die cost is a major factor, and to ensure economic manufacture parts must be made in sufficient quantity to render them reasonably competitive with items made by other methods. As an offset, even at this stage of development, elimination of much of the machining work necessary on conventionally produced parts is a feature which helps to balance costs.

Brightray Electrical-Resistance Materials

HENRY WIGGIN AND CO., LTD.: 'The Brightray Series of Electrical-Resistance Materials.'
Publn. 899,* 1955; 4 pp.

The alloys of the Brightray series are reviewed, with notes on the type of service for which each grade is specifically intended. The following varieties are covered:—

Brightray C: a long-life 80-20 nickel-chromium alloy widely used in the form of wire and tape. It is suitable for use in heating elements working at temperatures up to 1150°C. Principally used in domestic appliances and small industrial heating equipment.

Brightray S: very similar to the C alloy, but intended primarily for electric furnace heating elements working almost continuously at temperatures up to 1150°C., and hence supplied mainly as furnace strip and heavy-gauge wire.

Brightray B: incorporating a substantial percentage of iron, provides a cheaper but satisfactory material for elements working up to 950°C. Main application is for low-temperature heating elements where a shorter life and lower performance than is obtained with Brightray C can be tolerated.

Brightray F: is used for furnace elements operating at temperatures not exceeding 1000°C. It is recommended in preference to Brightray S where the furnace atmosphere is carburizing or is of such a character as to involve danger of green rot.

Brightray H: is intended for use in temperature conditions higher than those for which Brightray S is suitable. For further details of this alloy see following abstract.

HENRY WIGGIN AND CO. LTD.: 'Brightray H'.
Publn. 889,* 1955; 4 pp.

This modified 80-20 nickel-chromium alloy has been developed for elements used in the range 1100°-1250°C.

Oxidation-resistance of the new alloy at temperatures above 1100°C. is superior to that of the standard 80-20 nickel-chromium alloy: in laboratory tests, strip 0·088 mm. thick × 14 mm. wide, and rod, when heated continuously in air to 1250°C., have given lives of over 1,000 hours. The alloy has good strength at high temperatures and does not embrittle in service. Details of specific resistance are shown below:—

Temperature °C.	Approx. Specific Resistance microhms/sq. cm./cm.
20	126–130
500	130–136
1,000	122–127
1,300	124–126

The density of Brightray, at 20°C., is 7·8–8·1

High-Temperature Properties of Stainless Steels

E. A. LORIA: 'How Stainless Steels Rate for High-Temperature Aircraft Service.' *Iron Age*, 1955, vol. 175, Apr. 7, pp. 119–22; Apr. 14, pp. 103–6.

These articles review the properties, at elevated temperatures, of five types of steel which are considered to offer promise as materials of construction for high-speed aircraft:

Two ferritic 12 *per cent. chromium steels* modified by additions of molybdenum, tungsten and vanadium (Types 422 and 422 M).

A precipitation-hardening austenitic steel containing carbon 0·3, silicon 0·5, nickel 9·5, chromium 18·5, manganese 3·5, phosphorus 0·25, per cent. (Crucible HNM.)

A medium-chromium steel of which a typical composition is given as carbon 0·38, silicon 1·1, manganese 0·34, chromium 5·21, molybdenum 1·38, vanadium 0·40, per cent. (Halcomb 218.)

* *We shall be pleased to supply free copies of these publications.*

A complex chromium steel containing carbon 0·32, silicon 0·95, manganese 0·44, chromium 5, molybdenum 1·36, tungsten 1·31, vanadium 0·18, per cent. (Chro-Mow.)

Data are presented on mechanical properties, at normal and elevated temperatures, (in most cases up to about 1200°–1300°F.: 650°–705°C.), thermal-expansion characteristics, creep-resistance, and structural stability.

In the austenitic precipitation-hardening steel the best combination of mechanical properties is obtained by oil quenching from 2050°F. (1120°C.) and ageing at 1350°F. (730°C.) for 16 hours. A graph showing the effect of time and temperature of ageing, on the precipitation-hardening characteristics of the steel after solution treatment at 2050°F. (1120°C.) indicates that it is not prone to overageing. A limited number of tests already made on the HNM steel show that, for specimens solution treated at 2000°F. (1095°C.) and aged at 1400°F. (760°C.), stress-to-rupture at 1200°F. (650°C.) in 100 hours is of the order of 50,000 p.s.i. (22·3 tons per sq. in.), and that at 1350°F. (730°C.) it is about 28,000 p.s.i. (12·5 tons per sq. in.). Use of a higher temperature for the solution treatment results in longer life, but ductility is lowered. The following short-time tensile properties are claimed for the steel, in the condition produced by oil-quenching after heating at 2050°F. (1120°C.) for ½ hour, followed by heating for 16 hours at 1350°F. (730°C.).

Temperature of Test		U.T.S.		0·2% Yield Stress		Elongation	Reduction of Area
°F.	°C.	p.s.i.	t.s.i.*	p.s.i.	t.s.i.*	%	%
80	26	168,000	75·0	124,000	55·5	19·5	31·5
600	315	133,000	59·5	101,000	45·0	15·0	28·0
900	482	117,000	52·0	90,000	40·0	13·5	33·0
1,200	650	89,000	39·75	80,000	35·5	19·0	38·5
1,350	730	69,000	31·0	65,000	29·0	14·5	25·0
1,500	815	49,000	22·0	46,000	20·5	4·0	16·5

* To nearest ½ ton.

'Honeycomb' Metal Construction for High-Temperature Service

'Sandwich Structures for High-Temperature Service.' *Engineer*, 1955, vol. 199, Apr. 1, pp. 466–8.

Increasingly exacting speed and payload requirements of aircraft which have developed during recent years have led to a continuous search for materials of higher strength-to-weight ratio, and the advent of jet propulsion has added high temperature as a further factor affecting selection of steels and alloys. In the U.S.A. all-metal honeycomb structures are believed to hold much promise, and although sandwich material of this type is so new that relatively few established applications can yet be reported, an interesting stage of development has already been reached.

This article describes some of the work which has been done by Solar Aircraft Company and others in this connexion. Typical configuration of various forms of honeycomb cores is illustrated, and a comparison of strength-to-weight ratio as a function of temperature is given for a number of the materials which are being considered for sandwich structures for high-temperature use. These include titanium-stabilized austenitic nickel-chromium steel, precipitation-hardenable austenitic steel, Inconel 'X' (precipitation-hardening nickel-chromium-base alloy), Multimet (complex nickel-chromium-cobalt-base alloy), and other high-nickel and/or high-cobalt alloys. Fabrication by brazing, the mechanical properties of honeycomb structures at high temperatures, and potential applications of such material are also discussed.

Nickel Additions to Chromium-Molybdenum-base Steels

W. SIEGFRIED and F. EISERMANN: 'Better Steel Castings for High-Temperature Plant.' *Metal Progress*, 1955, vol. 67, Apr., pp. 100–1.

This note reports the experience of Sulzer Brothers, Winterthur, Switzerland, in development of steel castings for high-pressure steam boilers and turbines. The basis steel usually employed was of the following approximate composition: carbon 0·13, silicon 0·5, manganese 0·7, chromium 0·5, molybdenum 0·8, per cent., and in the course of experiments in modification of composition 0·2 per cent. of vanadium was added. Although showing an improvement in some properties, the vanadium-containing steels were found to be somewhat notch-sensitive: creep tests on notched bars gave lower rupture strengths than those made on smooth bars.

This note reports that both in the basis chromium-molybdenum and the vanadium-modified steels the embrittling tendency was eliminated by small additions of nickel or copper. Creep curves for tests of varying duration clearly demonstrate the progressively beneficial influence of nickel in amounts of 0·5–1·5 per cent.

Corrosion by Vanadium Pentoxide: Mechanism of Attack

G. LUCAS, M. WEDDLE and A. PREECE: 'The Liquidus of Metal-Oxide /V_2O_5 Systems, and the Mechanism of Accelerated Attack on Metals by V_2O_5.' *Jnl. Iron and Steel Inst.*, 1955, vol. 179, Apr., pp. 342–7.

The work reported in this paper is part of a general study of the corrosion of gas-turbine blades by vanadium pentoxide. The study of the metal oxide/vanadium pentoxide systems covered was not intended to be exhaustive, but was designed to establish the liquidus of the respective systems and the existence of certain metal vanadates, so providing information which could serve as a guide in selecting additive materials capable of combining with the vanadium in fuel oil and producing stable high-melting-point compounds. The systems studied were those formed by V_2O_5 with Al_2O_3, BeO, CaO, Co_3O_4, Cr_2O_3, MgO, NiO, CuO, Fe_2O_3, ZnO and Cr_2O_3–NiO. The Seger-cone method was used.

A study was also made of the accelerated oxidation of pure chromium resulting from vanadium pentoxide attack.

From the observations made, the authors conclude that it is not possible for a heat-resisting alloy which depends on chromium for its oxidation-resistance to be resistant to vanadium pentoxide unless some means is found to prevent the solution of vanadium ions in the chromic-oxide film. Tests made under standard conditions of time, temperature and vanadium-pentoxide addition, on binary alloys containing 20 per cent. of chromium with iron, *or* cobalt, *or* nickel, show progressively improving resistance to attack, from the iron alloys through to the nickel-base type. This confirms observations made by other investigators with regard to the relative resistance of more complex iron-rich and nickel-rich alloys to this type of attack. The mechanism responsible for the difference is discussed.

The authors' results, together with other data which support their observations, would indicate that there are two approaches to the problem:—

(1) Development of high-temperature alloys which depend for their oxidation-resistance on some element, other than chromium, which would form an oxide layer unaffected by the presence of vanadium pentoxide. At the present time the existence of such an oxide appears doubtful.

(2) Prevention of reaction of the vanadium pentoxide with the oxide film present on the blade, by adding to the fuel oil some substance which would combine with the vanadium pentoxide in the combustion chamber, to form an unreactive compound of high melting point.

There was earlier some promise that certain metal vanadates might be sufficiently unreactive to serve this purpose, but it now appears unlikely that they will be useful in this connexion, and that still more unreactive compounds must be sought.

Corrosion at Elevated Temperatures: Reference Data

NAT. ASSOCN. CORROSION ENGINEERS: 'High-Temperature Corrosion Data.' *Corrosion*, 1955, vol. 11, May, pp. 241t–5t: N.A.C.E. Publn. 55-6.

The National Association of Corrosion Engineers has assigned to its Unit Committee T 5B a study of the behaviour of metallic and non-metallic materials at high temperatures, arbitrarily defined as temperatures above 400°F. (205°C.). As its first project, the committee undertook a compilation of available high-temperature corrosion data, and this paper presents their findings.

The information is given in a series of tables in which thirty-one materials are rated in three categories, according to their behaviour in contact, at elevated temperatures, with aqueous and anhydrous corrodents.

A warning is given of the limited significance of the information so presented, since corrosion of any material of construction may be markedly influenced by variables such as welding, stress-relief treatment, external stress applied in service conditions, presence of crevices, impurity of the corrodent, agitation, aeration, etc. The data will, however, give a useful indication of the types of material which are worth detailed test as likely to be suitable for use in specific conditions.

The metallic materials for which data are recorded include steel, cast iron (plain and austenitic nickel-copper-containing types), copper-base alloys of various types, high-chromium and austenitic nickel-chromium stainless steels, Monel, nickel, Inconel, Hastelloy alloys A, B, C, and D, aluminium, and lead.

Hot Ductility of the Heat-Affected Zone in Welded Austenitic Steels

E. F. NIPPES *et al.*: 'The Heat–Affected Zone in Arc–Welded Type 347 Stainless Steel.' *Welding Jnl.*, 1955, vol. 34, Apr., pp. 169S–79S.

cf. paper to American Society of Mechanical Engineers, abstracted in *Nickel Bulletin*, 1955, vol. 28, No. 3, pp. 54–5.

S.A.E./A.M.S. Specifications for Heat- and Corrosion-Resisting Materials

Specifications recently issued by the Society of Automotive Engineers, in their Aeronautical Materials Series, include the following:

'Steel Castings, Precision Investment, Corrosion-Resistant.' *A.M.S.* 5355, issued Mar. 1, 1955; covering material of the composition shown below, to be used in small parts in which good corrosion-resistance, and strength at temperatures up to 600°F. (315°C.) are required.

Carbon 0·08 max., silicon 1·0 max., manganese 1·0 max., sulphur 0·04 max., phosphorus 0·04 max., chromium 15·5-17·5, nickel 3·0-5·0, copper 3·0-5·0, niobium + tantalum 0·45 max., per cent.

Solution and precipitation-hardening heat-treatments are specified, and tensile requirements are laid down.

'Steel Castings, Precision Investment, Corrosion- and Heat-Resistant (Low-Carbon)' *A.M.S.* 5370, issued Mar. 1, 1955;

covering material for small parts required to be corrosion- and heat-resistant at temperatures up to 800°F. (425°C.), and intended especially for parts which are to be welded. Suitable for parts requiring oxidation-resistance up to 1500°F. (815°C.), but useful at that temperature only when stresses are low: also for parts in contact with fuming nitric acid:—

> Carbon 0·050 max., silicon 1·0 max., manganese 1·0-2·0, sulphur 0·03 max., phosphorus 0·04 max., chromium 18·0-21·0, nickel 8·0-11·0, molybdenum 0·5 max., copper 0·5 max., per cent.

Solution heat-treatment is specified, and the castings are required, after sensitizing treatment, to pass the acidified copper-sulphate immersion test for susceptibility to intergranular corrosion. A related specification, *A.M.S.* 5371, issued Mar. 1, 1955, for sand castings, has a closely similar composition, except that silicon is 0·75–1·5, and sulphur 0·04 max., per cent.

'Steel, Corrosion- and Heat-Resistant', *A.M.S.* 5736, issued Mar. 1, 1955.

Bars, forgings and forging stock are covered, the material being primarily for parts such as turbine rotors, shafts, buckets, or blades, bolts, dowels and fittings requiring high strength up to 1300°F. (705°C.) and oxidation-resistance up to 1500°F. (815°C.). The composition range is as follows:—

> Carbon 0·08 max., silicon 0·40-1·00, manganese 1·00-2·00, sulphur 0·030 max., phosphorus 0·040 max., chromium 13·50-16·00, nickel 24·00-27·00, molybdenum 1·00-1·50, titanium 1·75-2·25, vanadium 0·10-0·50, aluminium 0·35 max., per cent.

Heat-treatment is detailed, and requirements are laid down for tensile properties at room temperature and stress-rupture properties at 1200°F. (648°C.).

Stainless Steel Specifications: Revision of A.I.S.I. Series

'Revisions in A.I.S.I. Stainless Designations Reflect Industry Practice.' *Iron Age*, 1955, vol. 175, May 19, pp. 122–3.

Comments on revised specifications issued by the AMERICAN IRON AND STEEL INSTITUTE, which exemplify easing of restrictions on certain elements previously in short supply, advances in melting technique, increased attention to free-machining grades, tendency towards lower carbon contents, and employment of niobium–tantalum stabilization as a means of conserving niobium.

The new schedules are shown on the opposite page.

Corrosion Inhibitors

M. BROOKE: 'Corrosion Inhibitor Checklist.' *Chemical Engineering*, 1954, vol. 61, Dec., pp. 230, 232, 234.

This summary is designed to assist the engineer who finds himself called upon to process a liquid in a vessel of a material not primarily intended to handle such liquid. Information culled from the literature (nearly 80 references are given) is arranged to show metals and alloys from which chemical equipment may be made, corrosive liquids with which such materials may be in contact, and inhibitors which have been recommended as minimizing attack.

NAT. ASSOCN. CORROSION ENGINEERS: 'Some Corrosion Inhibitors: a Reference List.' *Corrosion*, 1955, vol. 11, Apr. pp. 195t–7t: N.A.C.E. Publn. 55–3.

This publication is a report of the N.A.C.E. Technical Unit Committee T–3A on Corrosion Inhibitors. A tabular summary is made of chemical and trade names of inhibitors described in the literature, sources of supply (American only where specialized), and materials with which the inhibitors are effective. Reference is given to the original literature from which the information has been compiled. Nearly 70 inhibiting substances are included. No attempt has been made to evaluate the respective materials, and the compilers consider that the list is not complete, but it is issued at this juncture to provide a starting point for chemical engineers faced with unfamiliar corrosion problems. Suggestions for additions, eliminations and modifications are requested by the Committee responsible for the publication.

Effect of Neutron Bombardment on the Stability of Austenitic Nickel-Chromium Steel

M. B. REYNOLDS, J. R. LOW and L. O. SULLIVAN: 'Study of the Radiation Stability of Austenitic Type 347 Stainless Steel.' *Jnl. of Metals*, 1955, vol. 7, Apr.; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, 1955, vol. 203, pp. 555–9; T.P. 3974E.

Although much information is now available on the stability of austenitic steels of various types under ordinary conditions, the use of these materials in nuclear reactors has recently introduced an additional variable, the influence of which is not yet fully determined.

This paper reports results of tests in which a 20–11 per cent. chromium-nickel steel stabilized with niobium-tantalum was subjected to neutron bombardment and the structural changes were evaluated by a magnetic technique relating magnetic properties with ferrite content. Apparatus suitable for the measurement of the ferromagnetic saturation induction of small specimens is described.

It was found that slight increase in ferrite content results from neutron bombardment. This change in ferrite content increases with increasing initial ferrite concentration and with increasing radiation, up to a saturation point beyond which additional irradiation produces little effect. The similarity of the effect of irradiation to that of annealing is pointed out. The possible influence of irradiation on density is also discussed.

Type No.	C %	Mn % max.	P % max.	S % max.	Si % max.	Cr %	Ni %	Others %
301	0·15 max.	2·00	0·045	0·030	1·00	16·00–18·00	6·00–8·00	
302	0·15 max.	2·00	0·045	0·030	1·00	17·00–19·00	8·00–10·00	
302B	0·15 max.	2·00	0·045	0·030	2·00–3·00	17·00–19·00	8·00–10·00	
303	0·15 max.	2·00	0·20	0·15 min.	1·00	17·00–19·00	8·00–10·00	Mo, Zr 0·60* max.
303 Se	0·15 max.	2·00	0·20	0·06	1·00	17·00–19·00	8·00–10·00	Se 0·15 min.
304	0·08 max.	2·00	0·045	0·030	1·00	18·00–20·00	8·00–12·00	
304L	0·03 max.	2·00	0·045	0·030	1·00	18·00–20·00	8·00–12·00	
305	0·12 max.	2·00	0·045	0·030	1·00	17·00–19·00	10·00–13·00	
308	0·08 max.	2·00	0·045	0·030	1·00	19·00–21·00	10·00–12·00	
309	0·20 max.	2·00	0·045	0·030	1·00	22·00–24·00	12·00–15·00	
309S	0·08 max.	2·00	0·045	0·030	1·00	22·00–24·00	12·00–15·00	
310	0·25 max.	2·00	0·045	0·030	1·50	24·00–26·00	19·00–22·00	
310S	0·08 max.	2·00	0·045	0·030	1·50	24·00–26·00	19·00–22·00	
314	0·25 max.	2·00	0·045	0·030	1·50–3·00	23·00–26·00	19·00–22·00	
316	0·08 max.	2·00	0·045	0·030	1·00	16·00–18·00	10·00–14·00	Mo 2·00–3·00
316L	0·03 max.	2·00	0·045	0·030	1·00	16·00–18·00	10·00–14·00	Mo 2·00–3·00
317	0·08 max.	2·00	0·045	0·030	1·00	18·00–20·00	11·00–15·00	Mo 3·00–4·00
321	0·08 max.	2·00	0·045	0·030	1·00	17·00–19·00	9·00–12·00	Ti 5 x C min.
347	0·08 max.	2·00	0·045	0·030	1·00	17·00–19·00	9·00–13·00	Nb, Ta 10 x C min.
348	0·08 max.	2·00	0·045	0·030	1·00	17·00–19·00	9·00–13·00	Nb, Ta 10 x C min. Ta 0·10 max.
403	0·15 max.	1·00	0·040	0·030	0·50	11·50–13·00		
405	0·08	1·00	0·040	0·030	1·00	11·50–14·50		Al 0·10–0·30
410	0·15 max.	1·00	0·040	0·030	1·00	11·50–13·50		
414	0·15 max.	1·00	0·040	0·030	1·00	11·50–13·50	1·25–2·50	
416	0·15 max.	1·25	0·06	0·15 min.	1·00	12·00–14·00		Mo, Zr 0·60* max.
416 Se	0·15 max.	1·25	0·06	0·06	1·00	12·00–14·00		Se 0·15 min.
420	Over 0·15	1·00	0·040	0·030	1·00	12·00–14·00		
430	0·12 max.	1·00	0·040	0·030	1·00	14·00–18·00		
430F	0·12 max.	1·25	0·06	0·15 min.	1·00	14·00–18·00		Mo, Zr 0·60 max.
430F Se	0·12 max.	1·25	0·06	0·06	1·00	14·00–18·00		Se 0·15 min.
431	0·20 max.	1·00	0·040	0·030	1·00	15·00–17·00	1·25–2·50	
440A	0·60–0·75	1·00	0·040	0·030	1·00	16·00–18·00		Mo 0·75 max.
440B	0·75–0·95	1·00	0·040	0·030	1·00	16·00–18·00		Mo 0·75 max.
440C	0·95–1·20	1·00	0·040	0·030	1·00	16·00–18·00		Mo 0·75 max.
446	0·20 max.	1·50	0·040	0·030	1·00	23·00–27·00		N 0·25 max.
501	Over 0·10	1·00	0·040	0·030	1·00	4·00–6·00		Mo 0·40–0·65
502	0·10 max.	1·00	0·040	0·030	1·00	4·00–6·00		Mo 0·40–0·65

* At producer's option; reported only when intentionally added.

Stainless-Steel Spring Wire

SOC. AUTOMOTIVE ENGINEERS: 'Steel Wire, Corrosion-Resistant Precipitation Hardening, Spring Temper.' *S.A.E.* (*A.M.S.*) *Specn.* 5673, issued Mar. 1, 1955.

The specification covers material for springs requiring corrosion-resistance and resistance to permanent set at temperatures up to 600°F. (315°C.). Composition limits are shown below:—

Tensile, wrapping, and coiling tests are laid down, as well as requirements for general quality and for tolerances.

	%
Carbon	0·09 max.
Silicon	1·00 max.
Manganese	1·00 max.
Sulphur	0·030 max.
Phosphorus	0·040 max.
Chromium	16·00–18·00
Nickel	6·50–7·75
Aluminium	0·75–1·50

Stainless-Steel Tanks for Bulk Milk Transport

'Stainless Steel: A Market in Milk Hauling.' *Iron Age*, 1955, vol. 175, Apr. 21, p. 50.

This note calls attention to the rapid progress in development of the bulk milk-supply system in America, with particular reference to the significance of this movement in relation to consumption of stainless steel for tanks, etc. By 1953 it was reported that about 7,000 pick-up tanks had already been installed on farms in the U.S.A. and the number is now estimated at about 15,000. Groups of 20 farms are served by a pick-up truck carrying pumping equipment and a tank consisting of an inner stainless-steel shell and an outer shell of stainless steel or tough plastic. Transport tanks, of 2,500–4,000 gallons capacity (also of stainless steel), are used for distribution from the central collecting stations to receiving areas in various parts of the country. (In connexion with the introduction of the bulk-transport system into Britain, see abstract in *Nickel Bulletin*, 1955, vol. 28, No. 5, p. 95.)

Nickel-containing Materials Used in Chemical Feeding and Proportioning Equipment

R. W. HENKE: 'Chemical Feeding and Proportioning Equipment.' *Industrial and Engineering Chemistry*, 1955, vol. 47, Apr., pp. 684–95.

Chemical feeding equipment is defined as consisting of units designed to deliver a specific chemical treatment from a reservoir or other container into the medium to be treated, in a quantity determined by the displacement of the feeder itself. *Chemical proportioners* deliver the desired treatment in a quantity determined by a specific ratio of chemical to the quantity of medium being treated, maintaining this ratio constant regardless of the quantities involved.

This article reviews the criteria used in selecting equipment used for the two types of process, giving illustrated descriptions of some modern designs of feeding and proportioning plant. Materials of construction, metallic and non-metallic, used in such equipment are also considered and are classified in four categories (excellent, good, fair, unsatisfactory), according to their ability to resist attack by corrosive media handled in feeding and proportioning plant. The corrosives listed number over 400, and the materials graded according to their ability to resist attack by the corrodents include twelve types of non-metallic material, various grades of brass and bronze, nickel silver, Monel (nickel-copper alloy), Hastelloy D (nickel-silicon-aluminium alloy), six types of austenitic nickel-chromium stainless steels, three high-chromium steels, and cast iron. The positive information given is supplemented by an indication of conditions for which no data are known to be available.

Use of Monel for Protection of Steel in Marine Service

B. B. MORTON: 'Report on the Protection of Offshore Steel Structures by a Metallurgical Method.' *Amer. Soc. Mechanical Engineers, Petroleum Div.*, Sept., 1954; 25 pp. + figures.

This report outlines the steps taken to protect the 'critical area' of steel structures standing in sea water (chiefly in the Gulf of Mexico). The critical area is defined as the one affected by the splash from the surface of the sea, which cannot be protected by impressed current nor easily repainted after existing coatings have deteriorated.

Unprotected steel structures standing in sea water corrode at varying rates along their length; a 'corrosion profile' of steel piling, in relation to the position of mean high tide, mean low tide, the mud line, and sub-soil location, is shown in this paper.

In view of the likelihood that protection of the critical area is likely to be best effected by covering with a corrosion-resisting material, experiments have been made with Monel sheathing, and the results, reviewed and illustrated in detail in this paper, have demonstrated that this alloy is most suitable for the purpose. The paper comprises a history of tests made in the Gulf of Mexico and the conclusions are supported by a record of observations made at the Harbor Island Test Station, Wrightsville Beach, N.C.

Sheathing of Monel has been found to be more economical than the use of Monel-clad steel, which would, in any case be restricted to new structures. The thickness of Monel sheet to be used is determined by pitting which may occur during a 10–20 year period, and by consideration of the mechanical abuse to which the sheathing may be exposed in service. The author states that, at the time of writing, the general conclusion is that sheet of 0·062-in. thickness should be used on outside members, e.g. those exposed to contact with boats, and that a thinner gauge could be used for inside members. (The paper includes recommendations on application of sheathing of both types). From a practical standpoint it may be assumed that 'any thickness of sheet which can be satisfactorily applied and which is sufficiently heavy to withstand the mechanical abuse to be expected during service will not fail by corrosion during the desired life of a structure, e.g., of the order of 20 years.'

A note is added with regard to development of a cable suitable for suspending the magnesium anodes used for cathodic protection. The material used must be strong (to resist the pounding action resulting from the waves acting on the anodes), and to secure the necessary strength steel cables have been used, but these are subject to intense corrosion at the water level. Monel cable is now under test.

Monel Tanks in Fluorine Cells

See abstract on p. 108.

Corrosion- and Heat-Resisting S.G. Iron

See abstract on p. 110.

Etching Procedures for Phase Differentiation in High-Alloy Steels

F. BRAUMANN and G. PIER: 'Etching Procedures for Detection of Austenite, Ferrite, Sigma Phase and Carbides in High-Alloy Chromium and Chromium-Nickel Steels.' *Archiv f.d. Eisenhüttenwesen*, 1955, vol. 26, Mar., pp. 145–51.

This paper comprises a detailed experimental examination of the action of selected etchants on stainless steels of various types, with specific reference to the ability of the respective reagents to differentiate among the phases mentioned.

The solutions with which the tests were made were of the following types: methanol–aqua regia; ortho-nitrophenol solution; the Groesbeck etchant (an aqueous solution of potassium permanganate and sodium hydroxide); oxalic-acid solution. Heat-tinting was also employed.

The materials examined were typical straight-chromium, chromium–nickel (with and without molybdenum), and titanium-stabilized chromium–nickel steels. The action and selectivity of the respective reagents is examined, seriatim, as exemplified by photomicrographs showing effects produced on the various types of steel. The paper is thus essentially of a reference character.

An account is also given of an electrochemical procedure by which selective etching of a mixed austenite–ferrite structure can be ensured.

PATENTS

Methyl Sintered Accumulator Plates

Sintered plates are produced by preparing a suspension of carbonyl nickel powder in a viscous liquid containing a few per cent. of a lyophilic colloid (e.g., carboxymethycellulose), coating the plate (preferably a continuous perforated, nickel-plated band) with the suspension, and drying, preferably by infrared heating at 900°–1100°C. in a reducing atmosphere.

STÉ. ACCUMULATEURS FIXES ET DE TRACTION, S.A. *French Pat.* 1,077,036.

Nickel Electrodes for Accumulators

Porous electrodes for accumulators are produced by sintering and/or pressure treatment of light nickel powder obtained by thermal decomposition of nickel carbonyl. Uniformity of pore size is obtained by mechanically breaking down the coarser agglomerates to fine powder before sintering.

BADISCHE ANILIN- und SODA-FABRIK, A. G. *Brit. Pat.* 727,807 (similar to *German Pat.* 892,246, *and French Pat.* 1,055,278).

Nickel Oxide-Tungsten Oxide Catalyst

A nickel oxide–tungsten oxide catalyst is prepared by mixing an aqueous solution of ammonium metatungstate (pH 2–5) with an aqueous solution of a nickel salt (preferably nickel nitrate). A porous carrier is then impregnated with the solution and is dried and calcined.

J. B. MCKINLEY and W. A. PARDEE, assignors to GULF RESEARCH AND DEVELOPMENT CO. *U.S. Pat.* 2,703,789.

Production of Nickel Film by Decomposition of Nickel Carbonyl

The surface of an endless metal belt is oxidized and then brought into contact, in an inert atmosphere, with gaseous nickel carbonyl, preferably mixed with carbon dioxide, and is heated to 300°–400°F. (150°–205°C.), to decompose the gaseous metal compound and deposit metallic nickel on the belt as a thin film, which is subsequently stripped off.

P. PAWLYK, assignor to COMMONWEALTH ENGINEERING CO. *U.S. Pat.* 2,701,901.

Electrodeposited Nickel in Bearings

A composite bearing comprises a steel backing coated with an electrodeposited nickel layer, preferably 0·0003–0·0005 in. thick, onto which a layer of aluminium alloy, preferably containing tin 7–50 per cent., is bonded by heavy rolling.

GLACIER METAL CO., LTD., commn. from JOHNSON BRONZE CO. *Brit. Pat.* 729,761.

Nickel-Beryllium and Nickel-Magnesium Alloys for Electronic Use

Nickel–base alloys containing beryllium 2·5–4·5 per cent. or magnesium 0·5–2 per cent., and preferably subjected to a specified heat-treatment, are characterized by very high secondary emission and improved mechanical properties (e.g., Vickers hardness of 700–800).

STÉ. LE CARBONE LORRAINE (inventors, S. TESZNER and J. MILLET). *French Pat.* 1,085,073.

Nickel-containing Alloys for Watch and Instrument Springs

Wheels, levers and other parts of watches and instruments are made of an alloy containing up to

48 per cent. each of nickel and manganese (nickel+manganese being at least 50 per cent.), with cobalt 1–20 and copper at least 20 per cent. The alloys show physical properties which are specially suitable for such applications, combined with a good degree of oxidation-resistance.

R. STRAUMANN. *Brit. Pat.* 731,690.

Nickel-Manganese-Molybdenum Alloys in Ceramic-to-Metal Seals

In joining ceramics to metals the surface of the ceramic material is coated with a powdered mixture of manganese, nickel and molybdic oxide and sintered in position.

BRITISH THOMSON-HOUSTON CO., LTD.
Brit. Pat. 726,647.

Nickel-containing Brazing Alloy

A brazing alloy suitable for use in joining steel or copper-base alloys consists of silver 0·2–12, copper 10–50, nickel 9–12, silicon 0·1–1, per cent., balance zinc. Cadmium or tin 0·1–15 per cent. may also be present.

STÉ. DES SOUDURES CASTOLIN, S.A.
(inventor, R. D. WASSERMAN). *French Pat.* 1,077,373.

Nickel-Silicon-base Brazing Alloys for Ceramic-Metal Seals

Brazing alloys contain silicon 29–40 per cent., not more than 5 per cent. of at least one metal soluble in nickel, (e.g., iron, niobium, chromium, manganese, titanium, tungsten, gold or tantalum), balance nickel. Up to 25 parts of copper may also be present for every 100 parts of alloy. Typical compositions are quoted. The alloys are used in ceramic-metal seals.

WESTINGHOUSE ELECTRIC CORPN. (inventors, S. A. ROSENCRANS and M. H. BINSTOCK).
French Pat. 1,084,108.

Nickel-containing Propeller Alloys

Aluminium bronze suitable for cast marine propellers contains manganese 10–15, aluminium 6·5–9, iron 2–4, nickel 1·5–6, per cent., balance copper.

J. STONE AND CO., LTD. (inventors, R. J. M. PAYNE and A. W. O. WEBB). *Brit. Pat.* 727,021.

Nickel in Aluminium Alloys for Pistons

An aluminium alloy suitable for pistons contains copper 1·5–5, silicon 8–16, magnesium 0·3–1·5, nickel 1·5–6·0, 'cobalt 0·1–1.' titanium up to 0·3, iron up to 0·7, per cent.

C. PANSERI and S.A. ESERCIZIO DELL'INSTITUTO SPERIMENTALE DEI METALLI LEGGERI.
Italian Pat. 475,739.

Wear-Resisting Cast Irons

A wear-resistant cast iron, specially suitable for cylinder liners, contains carbon 2·5–4, silicon 1·6–3, manganese 0·6–1, chromium 0·1–1, nickel 0·1–0·45, titanium 0·05–0·35, phosphorus 0·3–0·7, per cent., balance iron. Vanadium, 0·05–0·15 per cent., may also be present.

GENERAL MOTORS CORPN. (inventor, F. J. WEBBERE).
Brit. Pat. 726,593 (similar to *U.S. Pat.* 2,691,576).

The wear-resistance of cast iron is improved by adding to a melt containing carbon 2·5–4, silicon 1·5–3, manganese 0·5–1, chromium 0·1–1, per cent. a ferrous-base intermediate alloy containing titanium (preferably 3·5–18 per cent.) and phosphorus (preferably 15–35 per cent.), and preferably also nickel 6–13 per cent.

GENERAL MOTORS CORPN. (inventor, F. J. WEBBERE).
Brit. Pat. 726,595.

Wear- and Corrosion-Resisting Alloy Cast Iron

A white cast iron combining desirable wear- and corrosion-resisting qualities contains carbon 3·0–3·7, silicon 0·5–3, nickel 4–8, chromium 4–15, manganese 0·2–1·5, per cent., balance iron. The carbon, silicon, nickel and chromium content are such that

$$\%C.+\frac{\%\,Ni}{28}+\frac{\%\,Cr}{24}+\frac{\%\,Si}{4}=4{\cdot}2\text{–}5{\cdot}0$$

MOND NICKEL CO., LTD. *Brit. Pat.* 727,061.

High-Alloy Corrosion-Resisting Cast Iron

A corrosion-resistant alloy cast iron consists of carbon 1·7–4, chromium, nickel, copper, molybdenum 0·4–36 per cent., silicon 1·25–5·6, manganese 0·2–3, sulphur 0·03–1, phosphorus 0·02–2, aluminium 0·05–1, per cent., balance (at least 50 per cent.) iron. A typical composition is cited as carbon 3·25, chromium 12·40, nickel 17·60, copper 5·70, molybdenum 7·20, silicon, manganese, sulphur, phosphorus, and aluminium within the limits shown above, balance iron.

K. SPITZ. *U.S. Pat.* 2,699,992.

Precipitation-Hardenable Nickel-Alloy Steel

A precipitation-hardenable steel contains nickel 3·5–6, aluminium 1·3–2·5, chromium 0·4–1·25, molybdenum 0·2–0·3, carbon 0·18–0·3, per cent., balance iron. If NiAl is 4·5–5·5, carbon is 0·25–0·30, and if NiAl is 5·5–7·5 carbon is 0·18–0·25 per cent. Vanadium up to 0·15, silicon up to 1, and manganese up to 1, per cent., may also be present. The steels are suitable for dies, gears and other wear-resistant machine parts.

F. B. FOLEY and C. C. CLARK, assignors to INTERNATIONAL NICKEL CO., INC. *U.S. Pat.* 2,708,159.

Complex Nickel-base Alloy for Gas-Turbine Components

An alloy for gas-turbine engine parts contains chromium 15–30, molybdenum 7·5–12, titanium 1–3, aluminium 0·1–2, carbon 0–0·3, iron 0·2, manganese 0–1·5, silicon 0–1·5, per cent., balance nickel. Cobalt up to 10 per cent. may also be present, but preferably only 0–1 per cent.

ROLLS-ROYCE, LTD. (inventors, H. E. GRESHAM and M. A. WHEELER). *Brit. Pat.* 730, 801.

Nickel-base Precipitation-Hardening Alloys for High-Temperature Service

Improved alloys for high-temperature service, e.g., in gas turbines, contain chromium 5–20, aluminium 0·5–5, titanium 0·5–3, molybdenum 0·5–10, boron 0·0003–0·009, carbon 0·01–0·25, zirconium 0·01–0·25, iron 0–5, manganese 0–4, silicon 0–2, copper 0–2, magnesium 0–0·1, per cent., balance nickel. The matrix-hardening factor (Cr+2Mo+Fe) is within the range 8–27 per cent., and relations between this factor and the precipitation-hardening factor (Al+Si) are specified. It is a feature of the composition that the alloys do not contain tungsten or niobium and that they need not contain cobalt. Heat-treatment, ¼–8 hours at 1800°–2200°F. (980°–1205°C.), air cooling or quenching, and heating for at least 1 hour at 1200°–1600°F. (650–870°C.) is also claimed.

MOND NICKEL CO., LTD. *Brit. Pat.* 728,375.

Low-Cobalt High-Temperature Alloys

Alloys for use at high temperatures, characterized by good stress-rupture properties and fatigue strength, ductility, and forgeability, contain carbon 0·1–0·2, chromium 18–20, molybdenum 6–11, cobalt 9–10, titanium 2·25–2·75, aluminium 0·25–1·25, manganese 0·5–1·5, silicon 0·3–1, iron not more than 5, per cent., balance nickel. A feature of the alloys is the low cobalt content and the absence of niobium.

GENERAL ELECTRIC CO. (inventor, R. B. JOHNSON). *Brit. Pat.* 730,133.

Sheet Metal for High-Temperature Service

An alloy capable of being rolled to sheet and offering good heat- and corrosion-resistance contains chromium 20–23, iron 17–20, molybdenum 8–10, cobalt up to 2·5, tungsten up to 1, manganese up to 1, silicon up to 1, carbon 0·05–0·15, per cent., balance nickel.

H. R. SPENDELOW and W. CRAFTS, assignors to UNION CARBIDE AND CARBON CORPN. *U.S. Pat.* 2,703,277.

Heat-Treatment of Creep-Resisting Nickel-base Alloys

Nickel–chromium–cobalt-base alloys of a type already generally used for creep-resisting components, but characterized by increased aluminium and titanium content and by the presence of very small amounts of zirconium and of boron, are subjected to heat-treatment comprising the following stages:—

Initial solution heating at 1150°–1250°C. (½–12 hours at 1150°C. and ¼–4 hours at 1250°C., with intermediate periods at intermediate temperatures).

An intermediate heating for at least 4 hours at a temperature above 1010°C., during which there is no substantial precipitation of a hardening phase.

A final precipitation-hardening treatment, e.g., for 16 hours at 700°C.

Improvements in properties effected by the triple treatment, as compared with those produced by the usual two-stage solution-hardening treatment, are demonstrated by reference to typical alloys used for turbine blading and other high-temperature applications. The range of composition to which the heat-treatment is applicable is given as follows:—chromium 15–25, cobalt 5–40, carbon 0–0·2, aluminium 1·5–2·5, titanium 2·8–4·0, iron 0–10, manganese 0–1·0, silicon 0–1·5, molybdenum 0–5, tungsten 0–5, niobium and/or tantalum 0–1, zirconium 0–0·2, boron 0–0·01, per cent., balance nickel.

MOND NICKEL CO., LTD. (inventors, W. BETTERIDGE, A. W. FRANKLIN and R. A. SMITH). *Brit. Pat.* 731,441.

Molybdenum-base Oxidation-Resisting Alloys

Oxidation-resistant alloys contain nickel 8–25, aluminium 1–5, chromium 0–25, per cent., balance molybdenum. The total of the molybdenum+nickel+aluminium+chromium is at least 97 per cent. A preferred composition is given as nickel 17, aluminium 2, manganese 0·1, silicon 0·2, zirconium 0·5, titanium 0·5 per cent., balance molybdenum.

L. J. JONES and E. WAINER, assignors to THOMPSON PRODUCTS INC. *U.S. Pat.* 2,698,786.

Electrical-Resistance Alloys

Long-life electrical-resistance heating alloys contain chromium 10–30, a trace to 0·50 per cent. of a rare-earth metal (preferably cerium and/or lanthanum), aluminium 0·01–1, calcium 0·01–0·2, zirconium 0–0·3, manganese 0–4, silicon 0–3, carbon up to 0·25, iron 0–8, per cent., balance (over 70 per cent.) nickel.

BRITISH DRIVER-HARRIS CO., LTD. *Brit. Pat.* 728,752.

Wear-Resisting Surface for Dies

The working surface of the dies for pressure die casting of cast iron or aluminium- or zinc-base alloys is made from material containing cobalt and/or nickel 5–50, with 0–10 per cent. of one or more of the carbides of chromium, niobium and tantalum, balance titanium carbide, titanium boride or titanium nitride.

R. F. KNOWLSON (inventors, R. F. KNOWLSON, D. H. SHUTE and T. W. PENRICE). *Brit. Pat.* 730,287.

Nickel-Zirconium Alloy in Hard Facing

A welding flux for the deposition of hard facings of tungsten carbide consists of 18–22 per cent. of a nickel–zirconium alloy (nickel 45, zirconium 26, aluminium 17, iron 4, silicon 4), graphite 27–33, iron oxide (haematite) 23–27, potassium metaborate 9–11, alumina 4–6, magnesia 4–6, lithium metaborate 4–6, per cent. A welding electrode with a metal tube containing tungsten carbide particles and the above flux is also claimed.

R. P. CULBERTSON and C. F. FOUCH, assignors to UNION CARBIDE AND CARBON CORPN. *U.S. Pat.* 2,700,091.

Nickel-Alloy Hard-Facing Rods

A welding rod for deposition of hard facings contains chromium 12–16, tungsten 12–16, cobalt 13–17, boron 2·5–3·5, carbon 0·6–1, silicon up to 1, manganese up to 0·25, iron up to 2 per cent., balance nickel. Molybdenum may replace tungsten.

S. G. MACNEILL and W. J. LINDNER, assignors to UNION CARBIDE AND CARBON CORPN. *U.S. Pat.* 2,699, 993.

Free-Machining Stainless Steel

A free-machining stainless steel having improved surface finish contains chromium 12–20, nickel 6·5–15, copper 2·5–5, sulphur or selenium 0·1–0·5, phosphorus up to 0·5, per cent., balance iron. Typical composition is chromium 13, nickel 14, copper 3, sulphur 0·3, carbon up to 0·15, balance iron.

W. C. CLARKE, assignor to ARMCO STEEL CORPN. *U.S. Pat.* 2,697,035.

Precipitation-Hardening Stainless Steel

A precipitation-hardenable stainless steel of low beryllium content and hardenable by treatment at comparatively low temperature contains carbon up to 0·2, silicon 2–4·5, chromium 17–21, nickel 7–14, molybdenum 1·5–4, beryllium 0·05–0·5, Mischmetall up to 0·3, per cent., balance iron. Preferred compositions are cited.

COOPER ALLOY FOUNDRY CO. (inventor, N. S. MOTT). *Brit. Pat.* 728,780.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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